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Finnish report on nuclear safety

Finnish 5th national report as referred to in Article 5 of the Convention on Nuclear Safety

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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Executive summary

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Fifth Review Meeting in April 2011.

There are two nuclear power plants operating in Finland: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units (Russian type pressurised water reactors), operated by Fortum Power and Heat Oy, and the Olkiluoto plant two BWR units (boiling water reactors), operated by Teollisuuden Voima Oyj. In addition, a new nuclear power plant unit is being constructed at the Olkiluoto site (PWR). At both sites there are interim storages for spent fuel as well as final repositories for medium and low level radioactive wastes. Furthermore, Triga Mark II research reactor is operated in Espoo by the Technical Research Centre of Finland.

In this report, latest development in the various topics of the Convention on Nuclear Safety is described. Major safety reviews and plant modernisations are explained, including safety assessment methods and key results. Safety performance of the Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered including some performance indicators. Major developments in Finland since the Fourth Review Meeting are as follows: amendment of the nuclear energy legislation in 2008, updating of safety guides, periodic safety review carried out at the Olkiluoto nuclear power plant in 2007–2009, continued construction of the new nuclear power plant unit, Olkiluoto 3, and assessment of the three Decision-in-Principle applications for constructing new nuclear power plants as well as two Decision-in-Principle applications for expanding the capacity of the future disposal facility for spent fuel.

In the report, the implementation of each of the Articles 6 to 19 of the Convention is separately evaluated. Based on the evaluation, the following features stressing Finnish safety management practices in the field of nuclear safety can be concluded:

- During the recent years Finnish legislation and regulatory guidance have been further developed and the work is still going on taking into account international guidance such as IAEA standards and WENRA (Western European Regulators' Association) reference levels for existing reactors and safety objectives for new reactors. No deviation from the convention obligations has been identified in the Finnish regulatory infrastructure including nuclear and radiation regulations.
- The licensees have shown good safety performance and rigorous safety management practices in carrying out their safety related responsibilities in the operation and modernisation of existing NPP's. During recent years, only minor operational events have taken place and no major safety problems have appeared. The licensees' practices are considered to comply with the Convention obligations.

- Safety assessment is a continuous process and living probabilistic risk assessment (PRA) practices are effectively used for the further development of safety. Periodic safety review of the Loviisa plant was carried out in 2005–2007 in connection with the operating licence renewal, and the periodic safety review of the Olkiluoto plant was carried out in 2007–2009. Methods for qualification of non-destructive testing and management of ageing have been developed further for responding to the needs of continuous safety improvement.
- The resources of the Radiation and Nuclear Safety Authority (STUK) are adequate to fulfil the needs for independent regulation, and have been increased to meet the needs to oversee the construction of the new plant in Finland. The regulatory guidance and practices have been further developed. The Technical Research Centre of Finland organisation, VTT, supports effectively the regulatory body in the safety assessment work providing safety analysis capabilities and tools e.g. via the national research programmes, and performing safety analyses.

The Fourth Review Meeting in 2008 identified some challenges and recorded some planned measures to improve safety in Finland. These issues are included and responded in this fifth national report of Finland. These items were (in brackets the Articles, in which the issues are addressed):
- ageing management of reactors in operation; renewal of I&C systems, reactor pressure vessel material embrittlement and use of risk-informed methods to further develop the plant safety (see Articles 14 and 18)
- maintaining competence and responding to the growing needs for professional staff (see Articles 8 and 11)
- restructuring, streamlining and updating the safety regulations, and developing risk informed regulation (see Articles 7 and 14)
- further enhancing the operating experience feedback processes (see Article 19)
- responding to increased demand for timely and effective communication to public (see Articles 8, 16, and 17)
- increased attention to information security issues (see Article 8)
- qualification of non-destructive testing (see Article 14)
- ensuring reliability of digital I&C, verification & validation (see Article 18)
- completing the PRA, e.g. the inclusion of fire events under shut down and low power conditions for Loviisa and Olkiluoto NPPs (see Article 14).

Still some of these issues require further development to enhance safety, i.e., including provision for plant ageing, reliability of digital I&C and risk informed regulation as well as management of competence taking into account the retirement. Other important issues cover new technologies, security arrangements and the growing need for new research and development programmes. These are generic issues that require international attention in all countries using nuclear energy.

Based on the amended Finnish nuclear energy legislation in 2008, the existing regulatory guidance system (YVL Guides) is being restructured. The goal is to have new regulatory guides published before the end of 2011. This task is highly prioritised because of new nuclear power plant projects in Finland.

The expected lifetime of the existing nuclear power plants requires renewal of systems and components and modernisation of technologies. The regulation of the existing nuclear power plants emphasises the management of ageing and the quality of plant operations. The I&C and other systems at the Loviisa and Olkiluoto plants are undergoing and planning modernisation, and extra care is needed to ensure operational safety during this work. In its regulatory inspections, STUK emphasises the importance of meticulous planning and controlled implementation of changes.

Security arrangements in the use of nuclear power also call for efficient supervision. The procedures, preparations and information exchange related to antiterrorism activities need to be enhanced worldwide. In Finland, the need for strengthened security has been addressed in the amended legislation and regulatory guidance. IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009. STUK has also increased its resources in the security area and its co-operation with other authorities.

The retirement of large age groups in Finland will affect public administration and industry throughout, including STUK and utilities. The plans for new construction and mentioned challenges and activities require additional manpower and efforts from the nuclear power companies and regulatory body as well as from technical support organisations. Thus, ensuring an adequate national supply of experts in nuclear science and technology and ensuring high quality research infrastructure are continuous challenges in Finland. The Ministry of Employment and the Economy is organising a new infrastructure working group which should start operating in fall 2010. Ageing manpower and organisations optimised for operation and control of current nuclear facilities require also continuous focus on resource management, education and training programmes and knowledge management. STUK's resources are developed in such a way that the key tasks in radiation and nuclear safety can be taken care of at all times. Both STUK and utilities have recruited new experts. Education and training programmes have been developed for newcomers at STUK as well as on national level to all organisations (such as utilities, waste management company and research organisations).

Due to the increasing interest in nuclear power in Finland, communication and information sharing on nuclear and radiation safety will become an increasingly important success factor for STUK and licensees. Regulatory processes and decisions have to be clear and understandable to general public. Interactions with media are important since media plays an important role in communication.

In conclusion, Finland has implemented the obligations of the Convention and also the objectives of the Convention are complied with. Safety improvements have been annually implemented at the Loviisa and Olkiluoto plants since their commissioning. Regulatory guidance have been further developed and the work is still going on taking into account safety research and advances in science and technology as well as the operating and construction experiences. There exists no urgent need for additional improvements to upgrade the safety of these plants in the context of the Convention.

Contents

1 Introduction

Finland signed on 20 September 1994 the Convention on Nuclear Safety which was adopted on 17 June 1994 in the Vienna Diplomatic Conference. The Convention was ratified on 5 January 1996, and it came into force in Finland on 24 October 1996. This report is the Finnish National Report for the Fifth Review Meeting in April 2011.

In Chapter 2 of this report, the measures related to each of the Articles 6 to 19 of the Convention are separately evaluated. The evaluation is based on the Finnish legislation and regulations as well as on the situation at the Finnish nuclear power plants. The reference is made to the IAEA Safety Requirements and other safety standards as appropriate. IAEA's Information Circular 572, Rev. 3, 28 September 2009, was used as a guideline for the context of the report.

In the report, latest safety reviews and plant modernisations are explained in detail including safety assessment methods and key results. Safety performance of Finnish nuclear power plants is also presented by using representative indicators. Finnish regulatory practices in licensing, provision of regulatory guidance, safety assessment, inspection and enforcement are also covered in detail.

The fifth National Report is aimed to be a stand-alone document and does not require familiarisation with the earlier reports. The fulfilment of the obligations of the Convention is described in general and the latest development since the Fourth Review Meeting is specifically described.

2 Compliance with Articles 6 to 19 – Article-by-article review

Article 6. Existing nuclear installations

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of the nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

In Finland, there are two nuclear power plants: the Loviisa and Olkiluoto plants. The Loviisa plant comprises of two VVER units that are operated by Fortum Power and Heat Oy (Fortum), and the Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oyj (TVO). TVO has also a Construction Licence for the new plant unit of nominal reactor thermal power 4300 MW at the Olkiluoto site (Olkiluoto 3). At both sites there are fresh and spent fuel storage facilities, and facilities for storage and treatment of low and medium level radioactive wastes. Other existing nuclear installations in Finland are the final disposal facilities for low and medium level radioactive waste at the Olkiluoto and Loviisa plant sites. The disposal facility at Olkiluoto was taken into operation in 1992 and at Loviisa in 1998.

For taking care of the spent fuel final disposal, a joint company Posiva Oy has been established by Fortum and TVO. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in 2020. The repository is planned to be constructed in the vicinity of the Olkiluoto NPP site. To confirm the suitability of the site, construction of an underground rock characterisation facility was commenced in 2004. Finnish Parliament endorsed in 2001 a Decision–in–Principle made by the Government for the implementation of Finnish Disposal Facility to the Olkiluoto site.

Finland observes the principles of the Convention, when applicable, also in other uses of nuclear energy than nuclear power plants, e.g. in the use of a research reactor. In Finland, there is one TRIGA Mark II research reactor (250 kW) situated in Espoo. The reactor was taken into operation in 1962 and it is operated by the Technical Research Centre of Finland (VTT).

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Nuclear Energy Act states that *the safety of nuclear energy use shall be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology.* The implementation of safety improvements has been a continuing process at both Finnish nuclear power plants since their commissioning and there exists no urgent need to upgrade the safety of these plants in the context of the Convention.

Loviisa NPP units 1 and 2

The Loviisa nuclear power plant units were connected to the electrical network in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original 1375 MW). The increase of the power level was implemented and licensed in 1998.

The latest overall safety review of the Loviisa plant took place in 2005–2007 in connection of the relicensing of the operation of the plant. The Loviisa plant was reaching its original design age in 2007–2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Based on the application, Radiation and Nuclear Safety Authority (STUK) carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Employment and the Economy (former Ministry of Trade and Industry) with its statement on the safety of the plant. The Finnish Government granted in July 2007 to Fortum new Operating Licences for unit 1 until the end of 2027 and for unit 2 until the end of 2030. The length of the Operating Licences corresponds to the current goal for the plant's lifetime, which is 50 years. Two periodic safety reviews (by the end of the year 2015 and 2023) are to be carried out by the licensee as a licence condition.

Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (see Article 14). For continued safe operation, plant improvement projects are still necessary. The largest ongoing improvement is the complete renewal of the plant I&C system, which is scheduled to be completed by 2014. Plant lifetime management includes credible procedures for following the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively.

Figure 1. Loviisa nuclear power plant.

In 2008, *the gross production of Loviisa 1 was 3850 GWh and the load factor was 86.0%. The annual refuelling and maintenance outage lasted 50 days. The gross production of Loviisa 2 was 4210 GWh, the load factor 93.9% and the length of the refuelling and maintenance outage was 22 days. The annual collective radiation doses were 1.13 manSv and 0.43 manSv for Loviisa 1 and Loviisa 2 respectively.*

In 2009, *Loviisa 1 produced 4290 GWh (gross), the load factor was 96.0% and the refuelling and maintenance outage lasted 17 days. In 2009 the gross production of Loviisa 2 was 4260 GWh, the load factor was 95.4%, and the refuelling and maintenance outage lasted 18 days. The collective radiation doses in 2009 were 0.42 manSv for Loviisa 1 and 0.34 manSv for Loviisa 2.*

One specific issue with Loviisa plant units is the risk of reactor pressure vessel brittle fracture. Several modifications have been made at the both units to reduce the risk. Fortum stated during the latest operating licence renewal process that the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The use of the reactor pressure vessel at the Loviisa unit 1 is licensed until the outage 2012 and at the Loviisa unit 2 until the outage 2010. The permit renewal of the reactor pressure vessels required Fortum to update the safety analyses. The application to extend the operation of the pressure vessel at the Loviisa unit 2 until the end of 2030, i.e., to the end of the plant unit's operating licence, is presently at STUK's review.

The large plant modernisation projects carried out at the Loviisa nuclear power plant and STUK's safety reviews are described in more detail in Annex 2. During recent years, only minor operational events have taken place and no major safety issues have appeared (see also Article 19).

In addition to the regulatory oversight and safety assessment, there have been independent safety reviews conducted by international organisations such as IAEA and WANO (World Association of Nuclear Operators). IAEA OSART (Operational Safety Review Team) missions have been organised at Loviisa power plant in November 1990 and March 2007. The WANO peer reviews have been carried out at the Loviisa nuclear power plant at the beginning of 2001 and in March 2010.

Olkiluoto NPP units 1 and 2

The Olkiluoto nuclear power plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018.

The latest periodic safety review (PSR) of the Olkiluoto plant took place in 2007–2009. Regulatory Guide YVL 1.1 specifies the contents of the PSR. For a separate periodic safety review without operating licence renewal, STUK shall be provided with similar safety-related reports as in applying for the operating licence or operating licence renewal. The PSR documentation was submitted to STUK for approval at the end of 2008 as required in the operating licence condition.

STUK made a decision concerning the PSR in October 2009. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK. Based on the assessment, STUK considered that the Olkiluoto nuclear power plant units 1 and 2 meet the set safety requirements for operational nuclear power plants. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning to improve safety. This is in line with the principle of continuous improvement of safety provided in Section 7 a of the Nuclear Energy Act. The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO submitted to STUK action plans for the observed points requiring improvement. STUK included also some additional requirements in the decision relating to the periodic safety review. These had to do among with among aother things systematic assessment and development of the diversity principle, including investigation of possibilities for residual heat removal independent of seawater, and plant modifications to improve safety in situations involving spurious opening of the turbine bypass valves.

Figure 2. Olkiluoto nuclear power plant units 1 and 2.

In 2008, *net production at Olkiluoto 1 was 7221 GWh and the load factor 93.7%. The annual refuelling and maintenance outage of Olkiluoto 1 lasted 18 days. The net production of Olkiluoto 2 was 6997 GWh and the load factor was 96.9%. The annual refuelling and maintenance outage of Olkiluoto 2 lasted 17 days. The collective radiation doses in 2008 were 0.73 manSv for Olkiluoto 1 and 0.21 manSv for Olkiluoto 2.*

In 2009, *net production at Olkiluoto 1 was 7296 GWh and the load factor was 97.0%. The annual refuelling and maintenance outage of Olkiluoto 1 lasted 8 days. The net production of Olkiluoto 2 was 7156 GWh and the load factor was 95.1%. The annual refuelling and maintenance outage of Olkiluoto 2 lasted 16 days. The collective radiation doses in 2009 were 0.40 manSv for Olkiluoto 1 and 0.79 manSv for Olkiluoto 2.*

As the result of the PSR, the physical protection of the Olkiluoto nuclear power plant was not yet considered to be completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue based also on the principle of continuous improvement were included in the decision relating to the periodic safety review.

The large plant modernisation projects carried out at the Olkiluoto nuclear power plant and STUK's safety reviews are described in more detail in Annex 2. During recent years, only minor operational events have taken place and no major safety issues have appeared (see also Article 19).

In addition to the regulatory safety assessment, there have been independent safety reviews conducted by international organisations. IAEA OSART mission has been organised at Olkiluoto in March 1986. The WANO peer reviews have been carried out at the Olkiluoto nuclear power plant at the end of 1999 and during the year 2006. A follow-up for the last WANO peer review was carried out in August 2009.

Olkiluoto NPP unit 3

Construction Licence application for the fifth nuclear power plant unit in Finland on the Olkiluoto site was submitted by TVO to the Ministry of Trade and Industry (predecessor of the Ministry of Employment and the Economy) in January 2004. The new unit, Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR), the design of which is based on the French N4 and German Konvoi type PWR's. A turn key delivery is provided by the Consortium Areva NP and Siemens. The technical requirements for Olkiluoto 3 unit were specified by using the European Utility Requirements (EUR) document as a reference. TVO's specifications complemented the EUR mainly in those points where Finnish requirements are more stringent. STUK gave its statement in January 2005 on nuclear safety based on the review of the licensing documentation and the Government issued the Construction Licence in February 2005.

Construction work is going on and next licensing step is the Operating Licence. Operating Licence is needed prior to loading nuclear fuel into the reactor core. Commercial operation is expected to be started in 2013. IAEA has agreed to carry out a pre-OSART (Operational Safety Review Team) mission to Olkiluoto NPP in late 2011 or 2012.

In conclusion, Finnish regulations and practices are in compliance with Article 6.

Figure 3. Olkiluoto NPP unit 3 in construction phase.

Article 7. Legislative and regulatory framework

1. ***Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.***
2. ***The legislative and regulatory framework shall provide for:***
   - *i.* ***the establishment of applicable national safety requirements and regulations;***
   - *ii.* ***a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a licence;***
   - *iii.* ***a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and the terms of licences;***
   - *iv.* ***the enforcement of applicable regulations and of the terms of licences, including suspension, modification or revocation.***

Legislative and regulatory framework

The current nuclear energy legislation in Finland (see Annex 1) is based on the Nuclear Energy Act originally from 1987. The Act has been amended 17 times during the years it has been in force: most changes are minor and originate from changes to other Finnish legislation. Nuclear energy legislation was updated and reformed in 2008 to correspond to current level of safety requirements and the new Finnish Constitution which came into force in 2000. Together with a supporting Nuclear Energy Decree originally from 1988, the scope of this legislation covers e.g.

- the construction and operation of nuclear facilities; nuclear facilities refer to facilities for producing nuclear energy, including research reactors, facilities for extensive disposal of nuclear wastes, and facilities used for extensive fabrication, production, use, handling or storage of nuclear materials or nuclear wastes
- the possession, fabrication, production, transfer, handling, use, storage, transport, export and import of nuclear materials and nuclear wastes as well as the export and import of ores and ore concentrates containing uranium or thorium.

The current radiation protection legislation is based on the Radiation Act and Decree, both of which are from 1991 and take into account the ICRP Publication 60 (1990 Recommendations of the International Commission on Radiological Protection). Section 2, General principles, and Chapter 9, Radiation work, of the Act are applied to the use of nuclear energy.

Based on the Nuclear Energy Act, the Government issued in 2008 the following regulations:

- Government Decree on the Safety of Nuclear Power Plants (733/2008)
- Government Decree on the Security in the Use of Nuclear Energy (734/2008)
- Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008)
- Government Decree on the Safety of Disposal of Nuclear Waste (736/2008).

The Decrees 733/2008 and 735/2008 are applied to a nuclear power plant which is defined to be a nuclear facility equipped with a nuclear reactor for the purpose of electricity or heat production or a complex consisting of nuclear power plant units and other related nuclear facilities located on the same plant site. The regulations are also applied to other nuclear facilities to the extent applicable. Decree 734/2008 is applied to all use of Nuclear Energy, i.e., it covers all nuclear facilities and activities.

The main reason for the 2008 amendment of the legislation was the need to include the basic safety requirements in the Nuclear Energy Act. Based on the rules of constitutionality all requirements having principal nature were transferred from the Decrees to the Act. One of the main principles of Finnish Constitution is, that all regulations affecting individual's rights have to be issued at the level of law. Also a need was recognised to move some current safety requirements from the level of regulatory guides to the Decrees in order to emphasise the essential safety significance of them.

Finland is a Member State of the European Union. The Nuclear Safety Directive (Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations) may affect Finnish nuclear legislation. Also, international peer reviews concerning physical protection and waste management, both carried out during the year 2009, may demand amendments to legislation. All these possible affects are currently under consideration.

Some other minor amendments were also made in nuclear and radiation legislation to reflect changes of other legislation (labour safety, criminal code). Amendments in other national legislation have not caused essential changes to the regulatory control of NPPs nor to the safety requirements set for them.

At the same time with the international negotiations to update the Paris and Brussels Conventions on Nuclear Liability also the Finnish Nuclear Liability Act was reviewed by a special governmental committee already in 2002. The financial provisions to cover the possible harms of a nuclear accident have been arranged according to the Paris and Brussels Conventions. A remarkable increase in the sum available for compensation of nuclear damages is expected in the future since international negotiations about the revision of the Paris/Brussels agreements on nuclear liability were successfully completed in 2004. In addition to the revised agreements, Finland has decided to enact unlimited licensee liability by law. This means, that insurance coverage will be required for a minimum amount of EUR 700 million and the liability of Finnish operators shall be unlimited in cases where nuclear damage has occurred in Finland and the third tier of the Brussels Supplementary Convention (providing cover up to EUR 1500 million) has been exhausted. The revised law will also have some other improvements, like extending the claiming period up to 30 years for victims of nuclear accidents. The law amendment (2005) has not taken effect yet. It will enter into force at a later date as determined by government decree. The entering into force of the amending act will take place as the 2004 Protocols amending the Paris and Brussels Conventions will enter into force. In Finland, the finishing off the international ratification process of the convention amendments without any undue delay is considered to be extremely important.

Provision of regulatory guidance

According to Section 7 r of the Nuclear Energy Act, STUK shall specify detailed safety requirements concerning the implementation of safety level in accordance with the Act. These guides are called YVL Guides. STUK shall specify the safety requirements it sets in accordance with the safety sectors involved in the use of nuclear energy, and publish them as part of the regulations issued by the STUK.

The safety requirements of STUK are binding on the licensee, while preserving the licensee's right to propose an alternative procedure or solution to that provided for in the regulations. If the licensee can convincingly demonstrate that the proposed procedure or solution will implement safety level in accordance with the Nuclear Energy Act, STUK may approve this procedure or solution.

The procedure to apply new guides to existing nuclear facilities is such that the publication of an YVL Guide does not, as such, alter any previous decisions made by STUK. After having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction, and to licensee's operational activities as well as to other nuclear facilities related to nuclear waste management and disposal and to the research reactor. To new nuclear facilities, however, the guides apply as such.

Nowadays the most important references considered in rulemaking are the IAEA safety standards and WENRA (Western European Nuclear Regulators' Association) reference levels. Other sources of safety information are worldwide cooperation with other countries using nuclear energy, e.g. MDEP (Multinational Design Evaluation Programme), VVER Forum and OECD/NEA. The Finnish policy is to participate in the international discussion on developing safety standards and adopt or adapt the new safety requirements into national regulations. At the moment STUK has a set of about 70 regulatory guides in force (see Annex 1). The regulatory guides have been continuously re-evaluated for updating.

After amending the nuclear energy legislation in 2008, also the revision of the existing YVL guide system has been commenced. The main objectives of this effort are the following:

- to restructure the guide system better to reflect the various areas of safety; at the same time to limit the total number of guides and need for cross-referencing between the guides
- to compile requirements concerning related safety issues to the same guide making it easier to use by the licensees and other stakeholders; also they will be coupled to the stage of licensing process
- to rewrite the separate requirements in such a way that each requirement will have its own number, be short and clearly stating who-what-when shall be doing something; requirements are expressed in shall-format, descriptive text is provided only when necessary
- when considering the requirements, special attention is paid for the opportunities to limit unnecessary prescriptiveness
- to update the contents of the regulatory guides, especially with the lessons learnt from the Olkiluoto unit 3 project.

A Safety management of a nuclear facility	**B** Plant and system design	**C** Radiation safety of a nuclear facility and environment	**D** Nuclear materials and waste	**E** Structures and equipment of a nuclear facility
A.1 Regulatory control of the safe use of nuclear energy	B.1 Design of the safety systems of a nuclear facility	C.1 Structural radiation safety of a nuclear facility	D.1 Regulatory control of nuclear non-proliferation	E.1 Manufacture and use of nuclear fuel
A.2 Siting of a nuclear facility	B.2 Classification of systems, structures and equipment of a nuclear facility	C.2 Radiation protection and dose control of the personnel of a nuclear facility	D.2 Transport of nuclear materials and waste	E.2 Construction plan of the mechanical components and structures of a nuclear facility
A.3 Management systems of a nuclear facility	B.3 Safety assessment of a NPP	C.3 Control and measuring of radioactive releases to the environmental of a nuclear facility	D.3 Handling of spent nuclear fuel	E.3 Regulatory control of the mechanical components and structures of a nuclear facility
A.4 Organisation and personnel of a nuclear facility	B.4 Nuclear fuel and reactor	C.4 Radiological control of the environment of a nuclear facility	D.4 Handling of low- and intermediate-level waste and decommissioning of a nuclear facility	E.4 Verification of strength of pressure equipment of a nuclear facility
A.5 Construction of a NPP	B.5 Reactor coolant circuit of a NPP	C.5 Emergency preparedness arrangements of a NPP	D.5 Final disposal of nuclear waste	E.5 In-service inspections of the mechanical components and structures of a nuclear facility
A.6 Operation and accident management of a NPP	B.6 Containment of a NPP			E.6 Buildings and structures of a nuclear facility
A.7 Risk management of a NPP	B.7 Preparing for the internal and external threats to a nuclear facility			E.7 Electrical and I&C equipment of a nuclear facility
A.8 Ageing management of a nuclear facility	B.8 Fire protection of a nuclear facility			E.8 Oversight of inspection organisations
A.9 Reporting on the operation of a nuclear facility				
A.10 Operating experience feedback of a nuclear facility				
A.11 Security arrangements of a nuclear facility				
Collected definitions of YVL-guides: a part of the regulations, but a separate document.				

Figure 4. The re-structured system of regulatory YVL Guides.

STUK has set an internal time schedule for this revision effort in such a way that all guides of the new system will be prepared at least to the level of a final draft before the end of 2010 and, that all restructured and updated guides will be published before the end of 2011. Considering the WENRA reference levels published in 2007 and 2008, the Finnish policy is to include all of them in the revised regulatory guide system. This is confirmed already during the work through a systematic approach to earmark all the reference levels to certain guides.

System of licensing

The licensing process is defined in the legislation. The construction and operation of a nuclear facility is not allowed without a licence. The licences are granted by the Government. The conditions for granting a licence are prescribed in the Nuclear Energy Act.

Before a Construction Licence for a nuclear power plant, nuclear waste disposal facility, or other significant nuclear facility can be applied, a Decision-in-Principle by the Government is needed. A condition for granting the Decision-in-Principle is that the operation of the facility in question is in line with the overall good of society. The municipality of the intended site of the nuclear facility has to be in favour of constructing the facility. There shall also be sufficient prerequisites for constructing the facility according to the Nuclear Energy Act: the use of nuclear energy shall be safe; it shall not cause injury to people, or damage to the environment or property.

The coming into force of the Decision-in-Principle further requires that it will be confirmed by the simple majority of the Parliament. The Parliament can not make any changes to the Decision; it can only approve it or reject it as it is. The parties involved in the Decision-in-Principle process and their tasks are described in Figure 5. In Decision-in-Principle phase STUK prepares a statement on safety and preliminary safety assessment concerning the applicant, the proposed plant designs and plant sites. STUK asks also a statement e.g. from the Advisory Commission on Nuclear Safety.

For the Construction and Operating Licence application, the Ministry of Employment and the Economy asks STUK's statement on safety.

***Decision-in-Principle procedure** was applied during the period November 2000 – May 2002 when Teollisuuden Voima Oyj (TVO) applied a Decision-in-Principle for the fifth NPP unit in Finland and the Government approved it and the Parliament confirmed the approval. The procedure was also applied when application for spent fuel repository was confirmed by the Parliament in 2001 and also in connection with accepting the Decision-in-Principle for expanding the capacity of spent fuel disposal facility to cover the spent fuel from the fifth reactor in May 2002. The Decision-in-Principle procedure was also applied during the period April 2008 – July 2010 when three applications for new nuclear power plants and two applications for expanding the planned capacity of the future spent fuel repository in Olkiluoto were handled by the Government and the Parliament (see Article 14).*

Construction and Operating Licence documents to be submitted to STUK for approval in this phase are defined in Sections 35 and 36 of the Nuclear Energy Decree. STUK asks also a statement e.g. from the Advisory Commission on Nuclear Safety. After receiving all statements for the Construction and Operating Licence, the Government will make its decision.

In accordance with Section 108 of the Nuclear Energy Decree, the different phases of construction of a nuclear facility may be begun only after STUK has, on the basis of the Construction Licence documents and other detailed plans and documents it requires, verified in respect of each phase that the safety-related factors and safety regulations have been given sufficient consideration.

Review of the detailed design of structures and equipment can be begun after STUK has found that the system-level design data of the system concerned are sufficient and acceptable. This assessment may take place as part of the review of the Preliminary Safety Analysis Report or separate system-specific descriptions, which are subsequently added to the Final Safety Analysis Report.

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. The purpose is to ensure that the safety and quality requirements, regulations for pressure equipment and approved plans are complied with and that the nuclear facility is constructed in other respects in accordance with the regulations. In particular, the oversight is aimed to verify that working methods ensuring high quality are employed for the construction.

Before loading fuel into the reactor, an Operating Licence is needed. The Operating Licences are granted for a limited period of time. This period has been at the beginning of Loviisa and Olkiluoto NPP operations five years and then about ten years. The periodic re-licensing has allowed good opportunities for a comprehensive, periodic safety review. Current operating licences of the Loviisa and Olkiluoto units are valid for about 20 years, but periodic safety reviews (PRS) are required as a condition of continued operation in the licences.

System of regulatory inspection and assessment

The legislation provides the regulatory control system for the use of nuclear energy. According to the Nuclear Energy Act, STUK is responsible for the regulatory oversight of the safety of the use of nuclear energy. The rights and responsibilities of STUK are provided in the Nuclear Energy Act. Safety review and assessment as well as inspection activities are covered by the regulatory oversight.

Oversight during operation

STUK's oversight during plant operation includes periodic inspection programme, continuous oversight performed by STUK's resident inspectores, regular reporting and reporting of events and over-

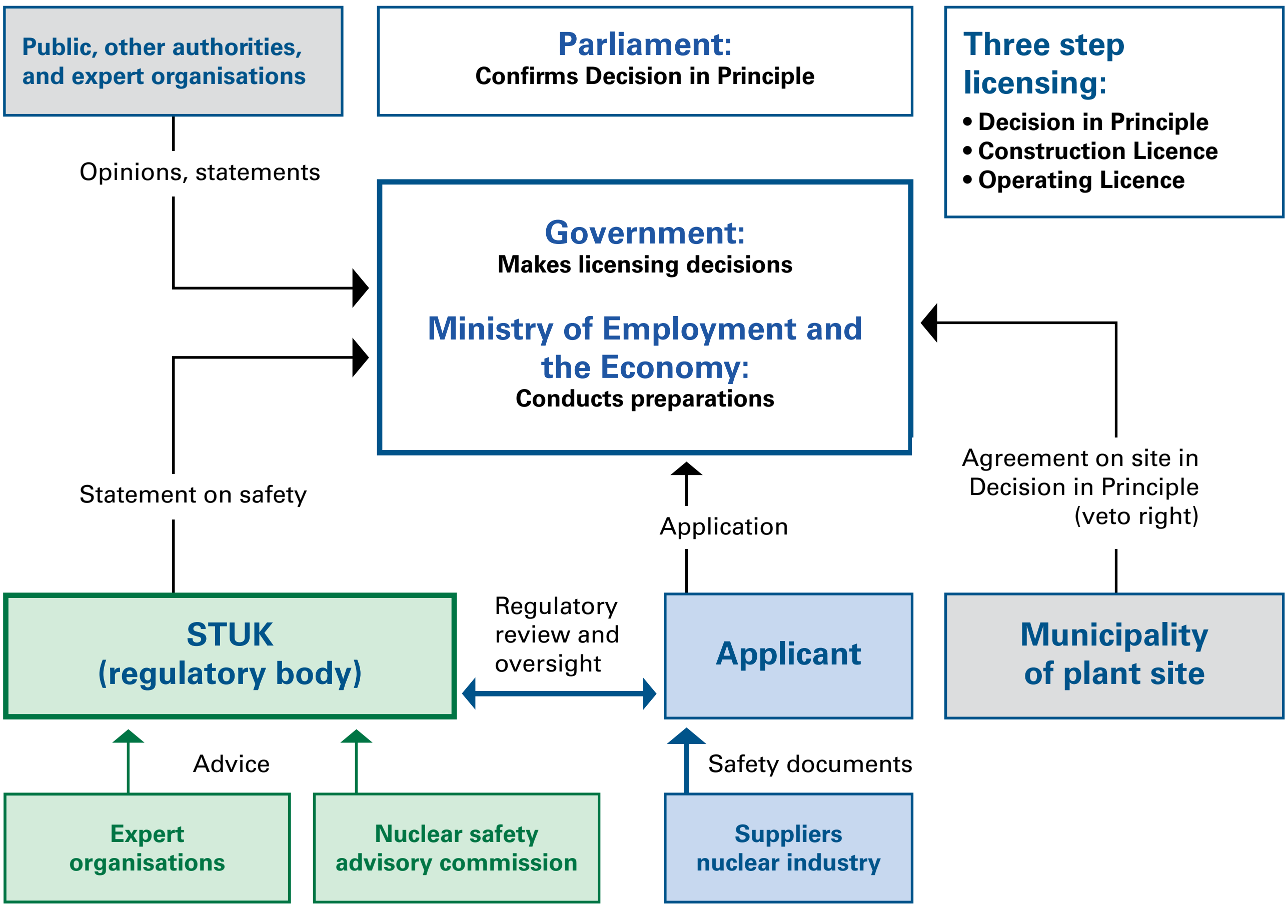


Figure 5. Licensing of nuclear facilities in Finland.

sight performed at the plant site during maintenance outages. STUK's periodic inspection programme is focused on the licensee's main working processes and covers the most relevant areas of nuclear power plant safety. Inspection programme has been modified during the years. Latest major renewal was in 1998 and since then the inspection programme has been slightly modified. Each year STUK defines the programme for the next year including additional inspections as needed. In addition to the periodic inspection programmes, STUK conducts ad-hoc inspections if seen necessary.

The objective of the inspection programme is to assess the safety level at the plants as well as safety management. Possible problems at the plants and in procedures of the operating organisations are to be recognised. STUK has put special emphasis on the management of the entire inspection programme, including the timely conduct, resource allocation and accurate reporting of results.

In the event review, first the safety significance of the event is evaluated based on the information given by the operator and STUK's resident inspectors. Later operational experience is reported to STUK as an event report, which STUK evaluates and may require additional information or actions. STUK maintains internal database for events which disseminates operating experiences and provides easy access to operational event reports. STUK may assign own investigation team for events deemed to have special importance, especially when the licensee's organisation has not been performing as planned and expected. It is also possible to nominate an investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. These inspections are usually conducted by a leadership of the STUK's event investigation manager, and an investigation team includes normally 3–5 experts from STUK or from external organisations nominated on case-by-case basis.

Numbers of operational events are followed through STUK's plant performance indicator system. Risk significance of operational events is followed by PRA based indicators.

STUK's oversight and safety assessment concerning plant modifications is described in Article 14.

Oversight during construction

In accordance with Section 109 of the Nuclear Energy Decree, STUK oversees the construction of the facility in detail. Oversight consists of inspections within the frame of the Construction Inspection Programme and inspections on manufacturing and construction of systems, structures and components important to safety. In addition, STUK has four resident inspectors overseeing the construction, installations and commissioning work at the Olkiluoto site. Licensee reports regularly about the progress of the construction.

To oversee the licensee's performance in a construction project, STUK has established a Construction Inspection Programme. The purpose of the programme is to verify that the performance and organisation of the licensee ensure high-quality construction and implementation in accordance with the approved designs while complying with the regulations and official decisions. The Construction Inspection Programme is divided into two main levels: the upper level assesses the licensee's general operations to manage the construction, such as safety management and culture, organisation, corrective actions programme, the licensee's expertise and use of expertise and project quality management. The next level, known as the operation level, assesses e.g. project quality assurance, training of the operating personnel, utilisation of the PRA, radiation safety, and licensee's review and assessment process for system, structure and component-specific design reviews and inspections in the various fields of technology. Furthermore, the emergency response arrangements during construction, physical protection, fire protection and nuclear waste treatment are subjects of the Construction Inspection Programme as far as the scope STUK considers necessary. In addition to the above-mentioned inspections, of which the licensee is informed in advance, STUK carries out inspections without prior notice at its discretion.

STUK performs inspections on manufacturing and construction of buildings, concrete and steel structures, and components as specified in YVL Guides. Inspections are determined when STUK reviews component or structure specific implementation plans. Inspections are defined either as hold or witness points. Licensee is responsible for inviting STUK to perform the inspection at a right time. Goal of the inspections is to verify that manufacturer, vendor and licensee have performed their duties as expected and that QC results of manufacturing and construction are acceptable. In addition, STUK performs inspections on installation and commissioning of systems, structures and components. The safety class of systems, structures and components is taken into account when determining the scope of inspections. On the licensee's application, STUK may approve separate inspection organisations to carry out specified regulatory control duties.

Enforcement

The Nuclear Energy Act defines the enforcement system and rules for suspension, modification or revocation of a licence. The enforcement system includes provisions for executive assistance if needed and for sanctions in case the law is violated. The enforcement tools and procedures of the regulator are considered to fully meet the needs.

In practice, the enforcement tools include: oral notice or written request for action by the inspector, and written notice or order for actions by STUK. Actions can include shutting down the plant operation immediately or decrease of reactor power and for unlimited time. Legally stronger instruments would be 1) setting a conditional imposition of a fine, 2) threatening with interruption or limiting the operation and, 3) threatening that STUK enforces the neglected action to be made at the licensee's expense.

The repertoire of these tools together with some practical examples for implementing them has been presented in an internal policy document as part of STUK's Quality System.

In conclusion, Finnish regulations and practices are in compliance with Article 7.

Article 8. Regulatory body

1. ***Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.***
2. ***Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.***

STUK in the regulatory framework

According to the Nuclear Energy Act, the overall authority in the field of nuclear energy is the Ministry of Employment and the Economy. The Ministry prepares matters concerning nuclear energy to the Government for decision-making. Among other duties, the Ministry of Employment and the Economy is responsible for the formulation of a national energy policy.

The mission of the Radiation and Nuclear Safety Authority (STUK) is 'to protect people, society, environment, and future generations from harmful effects of radiation'. STUK is an independent governmental organisation for the regulatory control of radiation and nuclear safety. STUK is administratively under the Ministry of Social Affairs and Health. Interfaces to ministries and governmental organisations are described in Figure 6. It is emphasised that the regulatory control of the safe use of radiation and nuclear energy is independently carried out by STUK. No Ministry can take for its decision-making a matter that has been defined by law to be on the responsibility of STUK. STUK has no responsibilities or duties which would be in conflict with regulatory control. STUK's Advisory Committee was established in March 2008. Advisory Committee helps STUK to develop its functions as a regulatory, research and expert organisation in such a way that the activities are in balance with the society's expectations and the needs of the citizens. Advisory Committee can also make assessments of the STUK's actions and give recommendations to STUK.

The current Act on STUK was given in 1983 and the Decree in 1997. According to the Decree, STUK has the following duties:

- regulatory oversight of safety of the use of nuclear energy, emergency preparedness, security and nuclear materials
- regulatory control of the use of radiation and other radiation practices

- monitoring of the radiation situation in Finland, and maintaining of preparedness for abnormal radiation situations
- maintaining national metrological standards in its field of activity
- research and development work for enhancing radiation and nuclear safety
- informing on radiation and nuclear safety issues, and participating in training activities in the field
- producing expert services in the field of its activity
- making proposals for developing the legislation in the field, and issuing general guides concerning radiation and nuclear safety
- participating in international co-operation in the field, and taking care of international control, contact or reporting activities as enacted or defined.

STUK has the legal authority to carry out regulatory oversight. The responsibilities and rights of STUK, as regards the regulation of the use of nuclear energy, are provided in the Nuclear Energy Act. They cover the safety review and assessment of licence applications, and the regulatory oversight of the construction, operation and decommissioning of a nuclear facility. The regulatory oversight of nuclear power plants is described in detail in the Guide YVL 1.1. STUK has e.g. legal rights to require modifications to nuclear power plants, to limit the power of plants and to require shutdown of a plant when necessary for safety reasons, as described in Article 7.

STUK does not grant any construction or operating licences for nuclear facilities. However, in practice no such licence would be issued without STUK's statement where the fulfilment of the safety regulations is confirmed as described in Article 7.

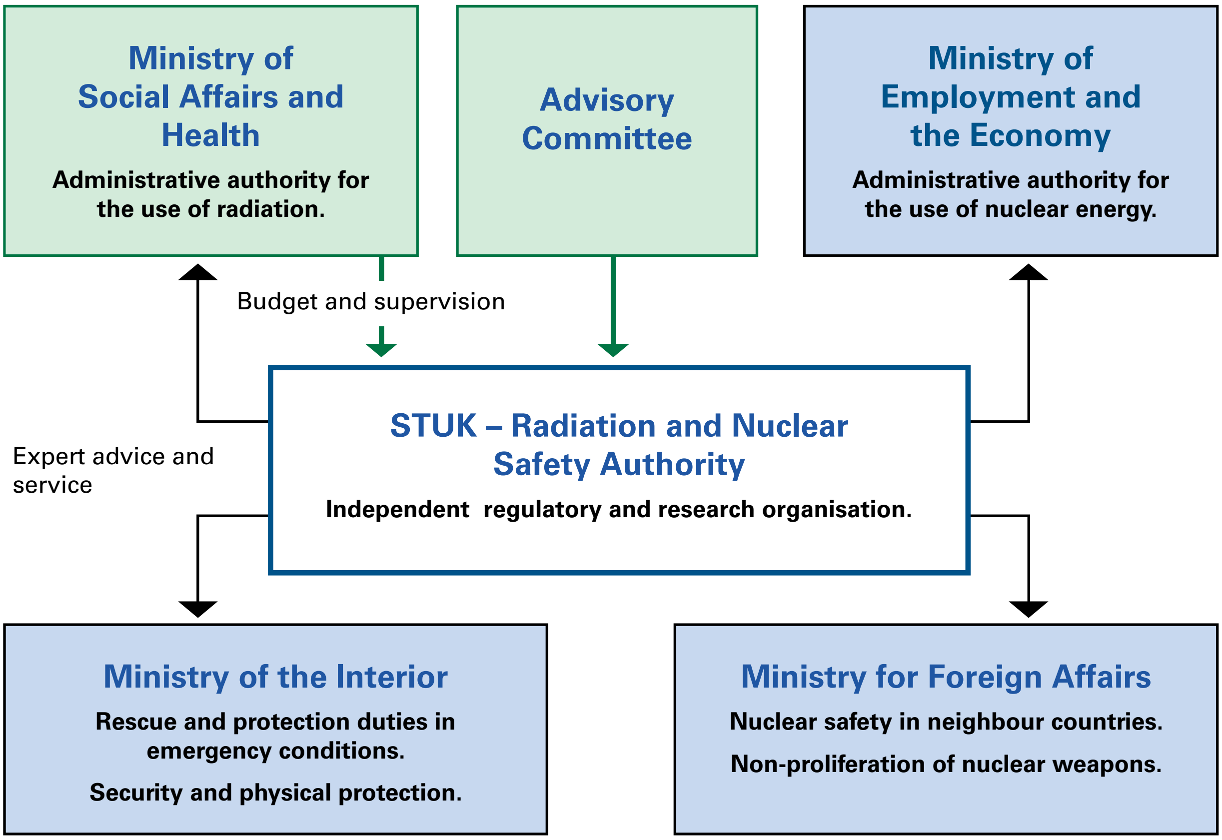


Figure 6. Co-operation and interfaces between STUK and Ministries and other organisations.

An Advisory Commission on Nuclear Safety has been established in 1998 by a Decree. This Commission gives advice to STUK on important safety issues and regulations. The Commission also gives its statements on licence applications. The Commission has now two international committees, one for reactor safety and one for waste safety issues. In addition, an Advisory Committee on Radiation Safety has been established for advising the Ministry for Health and Social Affairs. The members of the Advisory Commission on Nuclear Safety and the Advisory Committee on Radiation Safety are nominated by the Government.

To assist STUK's work in nuclear security, an Advisory Committee on Nuclear Security was established in 2009. The members of the committee come from the various Finnish authorities, and the nuclear licencees also have their representatives. The duties of the committee include the assessment of the threats in the nuclear field as well as consultation to STUK in important security issues. The committee also aims to follow and promote both the international and internal co-operation in the field of nuclear security.

STUK is responsible for informing the public and media on radiation and nuclear safety. STUK aims to communicate proactively, openly, timely and understandably. A prerequisite for successful communication is that STUK is known among media and general public and the information given by STUK is generally regarded as truthful. Communication is based on best available information. STUK's web site is an important tool in communication. It is important that the web pages are professionally edited and updated regularly. The information on web pages must be easy to find and understandable. Internal communication provides the personnel information about STUK's activities and supports its capability in participating in the external communication.

STUK's operations have been assessed by a peer review. Full-scope IRRT mission (IAEA's International Regulatory Review Team) was carried out in 2000 and a follow-up mission in 2003. IRRS mission (IAEA's Integrated Regulatory Review Service) has been agreed with the IAEA to be carried out in October 2012.

Finance and resources of STUK

The organisational structure and the responsibilities within STUK are described in the Management System of STUK. Also processes for regulatory oversight and other activities of STUK are presented in the Management System. The organisation of STUK is described in the Figure 7.

STUK receives about 34% of its financial resources through the government budget. However, the costs of regulatory oversight are charged in full to the licensees. The model of financing the regulatory work is called net-budgeting model and it has been applied since 2000. In this model the licensees pay the regulatory oversight fees directly to STUK. In 2009, the costs of the regulatory oversight of nuclear safety were 16 million €.

STUK has adequate resources to fulfil its responsibilities. The net-budgeting model makes it possible to increase for example personnel resources based on needs in a flexible way.

At the end of 2009, number of staff in the department of Nuclear Reactor Regulation was 106.

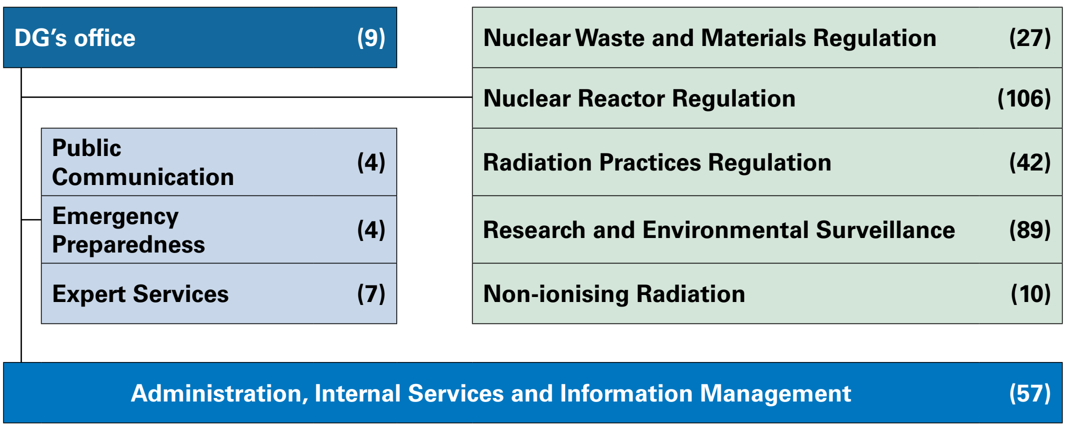


Figure 7. Organisation of STUK. Figures indicate the number of staff in the organisational unit. The total number of staff at the end of 2009 was 355.

The number of staff has increased by 11 since the time of the fourth review meeting. The expertise of STUK covers all the essential areas needed in the oversight of the use of nuclear energy. As needed STUK orders independent analyses, review and assessment from technical support organisations to complement its own review and assessment work. The main technical support organisation of STUK is the Technical Research Centre of Finland (VTT), but also Aalto University (former Helsinki University of Technology) and Lappeenranta University (LUT) of Technology are important. Also international technical support organisations and experts have been used, especially to support review and inspection activities related to Olkiluoto unit 3.

New personnel have been recruited since 2003 mainly for the safety review and assessment and inspection activities related to the Olkiluoto unit 3. The number of personnel in the department of Nuclear Reactor Regulation over the period of 2001–2009 is shown in Figure 8. The resources used for the oversight of existing nuclear power plants (Loviisa units 1 and 2 and Olkiluoto units 1 and 2), Olkiluoto unit 3 which is under construction and new plant projects (Loviisa unit 3, Olkiluoto unit 4 and Fennovoima's unit 1) are shown in Figure 9. Annual volume of the oversight of the Olkiluoto unit 3 construction has been increasing every year about 35 person years for the Olkiluoto 3. Starting from year 2003, inspection organisations have been performing construction inspections in lower safety classes.

STUK has also increased the number of personnel in the area of plant security. In 2009, a separate unit for security with three experts was founded in the department of Nuclear Reactor Regulation.

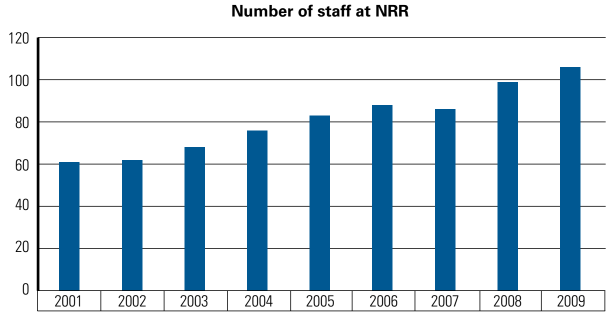


Figure 8. Number of personnel in the department of Nuclear Reactor Regulation.

The updating of ***regulatory guides on security arrangements*** *is included in the ongoing rule-making activity. IAEA's International Physical Protection Advisory Service (IPPAS) mission was carried out in Finland in 2009. In addition to this effort to strengthen the regulatory control of plant security arrangements, STUK has also systematically audited and improved its own internal information security. I.a. the reliability and protection of data connections between STUK's site personnel and STUK headquarters have been audited by third party experts and the e-mail traffic to and from the licensees has been encrypted. When purchasing the office data equipment as well as laptops for the inspectors the information security is given full attention. The whole personnel at STUK took part in the information security training course in 2009.*

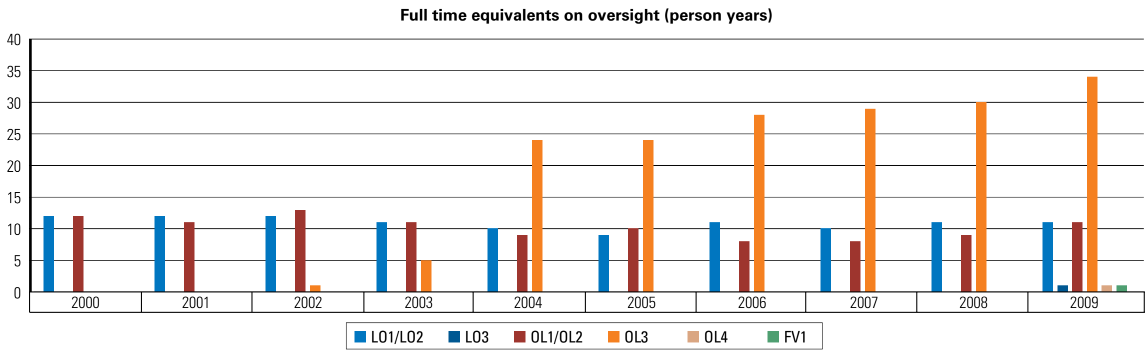


Figure 9. The resources used for the regulatory oversight in full time equivalents.

Ensuring competence

The management of STUK highlights the need for competent workforce. STUK has adopted a competence management system and nuclear safety and regulatory competencies are also emphasised in STUK's strategy. Implementation of the strategy is reflected into the annual training programmes, on the job training and new recruitments. The national nuclear safety and waste management research programmes have an important role in the competence building of all essential organisations involved in nuclear energy. These research programmes have two roles: for the first ensuring the availability of experts and for the second ensuring the on-line transfer of the research results to the organisations participating to the steering of the programmes and fostering the expertise. STUK has an important role in the steering of these programmes.

Most of the professional staff of STUK conducting safety assessments and inspections has a degree of university level. The average experience of the staff is about 15 years in the nuclear field. The competence analysis is carried out on regular basis and the results are used as the basis for the training programmes and the new recruitments. The training programme includes internal courses as well as courses organised by external organisations. On an average 5 % of the annual working hours has been used to enhance the competence.

An induction programme is set up at STUK for all new recruited inspectors. In addition to administrative issues, the induction programme includes familiarisation with legislation, regulatory guidance and regulatory oversight practices. Programme is tailored to each new inspector and followed by the manager.

STUK has participated in the preparation and execution of a basic professional training course on nuclear safety with other Finnish organisations in the field. The first 6-week course commenced in September 2003 and the 8th basic professional training course will commence in autumn 2010. At the moment, about 400 newcomers and junior experts, of whom more than 60 have been from STUK, have participated in these courses. The content and structure of the course has been enhanced according to the feedback received from the participants.

In Finland, VTT is the largest research organisation in the field of nuclear energy. At VTT, about 200 experts are working in the field of nuclear energy, half of them full-time. The total volume of the nuclear energy research in the year 2009 was over 50 million € (of the Ministry of Employment and the Economy estimate). This figure includes also research made by GTK (Geological Survey of Finland), LUT (Lappeenranta University of Technology) and Aalto University (former Helsinki University of Technology, HUT).

The Nuclear Energy Act was amended in 2003 to ensure funding for a long term nuclear safety and nuclear waste management research in Finland. Money is collected annually from the licence holders to a special fund. Regarding nuclear safety research the amount of money is proportional to the actual thermal power of the licensed power plants or the thermal power presented in the Decision-in-Principle. For the nuclear waste research, the annual funding payments are proportional to the current fund holdings for the future waste management activities.

The research projects are selected so that they support and develop the competences in nuclear safety and to create preparedness for the regulator to be able to respond on emerging and urgent safety issues. The key topics of the recent nuclear safety research programme (SAFIR2010) are the behaviour of reactor, the properties of containment and the ageing management of nuclear power plants. There are also research projects in the field of the assessment of the safety culture of an organisation. The amount of money collected from the licensees in year 2009 was about 3 million € for nuclear safety research. The research projects have also additional funding from other sources. The total volume of the programme in 2010 is 7 million €. The research programme SAFIR2010 was evaluated by external experts in 2010 and the programme was considered to fulfil its objectives.

In the Finnish research programme on nuclear waste management (KYT2010) the research is distributed into strategic topics of nuclear waste management as well as into research areas connected with the long-term safety of the final disposal of nuclear wastes. The programme is conducted during 2006–2010 and its target volume is around 1 million € per year.

In conclusion, Finnish regulations and practices are in compliance with Article 8.

Article 9. Responsibility of the licence holder

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.

The responsibility for the safety rests with the licensee as prescribed in the Nuclear Energy Act. According to Section 9 of the Act, it shall be the licensee's obligation to assure safe use of nuclear energy. Furthermore, it shall be the licensee's obligation to assure such physical protection and emergency planning and other arrangements, necessary to ensure limitation of nuclear damage, which do not rest with the authorities.

It is the responsibility of the regulatory body to verify that the licensees fulfil the regulations. This verification is carried out through continuous oversight, safety review and assessment as well as inspection programmes established by STUK. In its activities, STUK emphasises the licensee's commitment to the strong safety culture. The obvious elements of licensee's actions to meet these responsibilities are strict adherence of regulations, prompt, timely and open actions towards the regulator in unusual situations, active role in developing the safety based on improvements of technology and science as well as effective exploitation of experience feedback. In addition to inspections and safety assessment, the follow-up of licensee's efforts in achieving results is based on safety indicators. This system includes indicators e.g. for plant availability, incidents, probabilistic risk assessment results, safety system operability, radiation doses to personnel as well as releases to environment.

Based on the Chapter 7 of the Nuclear Energy Act, to ensure that the financial liability for the future management and disposal of nuclear wastes and for the decommissioning of nuclear facilities is covered, the nuclear power companies are every third year obliged to present estimates for future costs of these operations and take care that the required amount of money is set aside to the State Nuclear Waste Management Fund. In order to provide for the insolvency of the nuclear utilities, they shall provide securities to the Ministry of Employment and Economy for the part of financial liability which is not yet covered by the Fund. At the end of the year 2009 the funded money (1 800 million euros) covered most part of whole liability (2 080 million euros). Remaining 280 million euros were to be covered by payment of 88 million euros in 2010 and securities.

The arrangements for the Olkiluoto unit 3 will follow the same lines. The licensee with a waste management obligation shall submit the waste management scheme and the calculations of waste management costs, which are based on the scheme, to the Ministry for approval for the first time early enough before beginning the operations producing nuclear waste, and at the latest in connection with the operating licence application. The waste management scheme shall cover all phases of waste management including the decommissioning and the final disposal. The scheme must be sufficiently detailed to allow the calculations for the assessed liability.

The financial provisions to cover the possible damages to third parties caused by a nuclear accident have been arranged in Finland according to the Paris and Brussels Conventions. Related to the revision of the Paris and Brussels Conventions in 2004, Finland has decided to enact unlimited licensee's liability by law (see Article 7). The revised law will also have some other modifications, such as extending the claiming period up to 30 years for victims of nuclear accidents. These changes are still in 2010 pending on the international ratification of the Paris and Brussels Conventions.

In conclusion, Finnish regulations and practices are in compliance with Article 9.

Article 10. Priority to safety

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

Regulatory requirements regarding safety management

The importance of a good safety culture is emphasised in the Nuclear Energy Act and in the Government Decree on the Safety of Nuclear Power Plants (733/2008, Sections 21, 28 and 29), which state that when designing, constructing, operating and decommissioning a nuclear power plant, a good safety culture must be maintained by making sure that the decisions and activities of the entire organisation reflect commitment to safety. An open working atmosphere must be promoted to encourage identification, reporting and elimination of factors endangering safety, and the personnel must be given opportunity to contribute to the continuous enhancement of safety.

According to the Nuclear Energy Act, a responsible director has to be appointed for the construction and operation of a nuclear power plant. The appointment is subject to approval by STUK. The responsible director has a duty to ensure the safe use of nuclear energy and to see that the arrangements for physical protection and emergency preparedness and the safeguards control are complied with. The responsible director must have real possibilities to take effectively care of this duty.

STUK's Guide YVL 1.4 sets general requirements for management systems and has been updated in 2008. The new YVL 1.4 is based on IAEA GS-R-3, and it includes several requirements for promoting good safety culture: The management system must support the characteristics of the organisational culture that promote good safety culture, and the management must express its commitment to safety. The procedures used must strengthen a vigilant, questioning and initiative attitude at all levels of the organisation. The management system must also contain procedures for identification and continuous promotion of safety culture.

Measures taken by licence holders

Loviisa NPP

At the Loviisa NPP, there is an organisational unit for safety that is independent of the units that are directly responsible for the operation of the plant. In addition, independent advisory body for safety issues have been established in Loviisa, including a nuclear safety committee with external expert members. Fortum has also established documented quality and safety policies for the Loviisa NPP.

In recent years, Fortum has been actively seeking international evaluations of safety management and procedures at the Loviisa NPP in order to improve its own operations. STUK considers this to be a positive indication of the improved openness of the organisation, its search for good practice and commitment to long-term development work. IAEA carried out an OSART safety review in Loviisa in March 2007, with a follow-up review in July 2008. Based on these reviews, IAEA stated that some development actions were completed where as some have not been initiated and many are still in progress, although they have been appropriately started. WANO peer review was performed in March 2010.

Due to changes in Fortum's organisation, the responsible director at the Loviisa NPP changed in 2008 and then again in 2009. In addition, a restructuring of the unit responsible for safety at the Loviisa NPP has taken place, and new employees have been recruited for the unit.

Fortum has developed a special training programme for the Loviisa NPP contractors, with which the licensee aims to ensure the right attitudes and safety culture among the contractors working at the NPP. In the training, Fortum communicates the safety-first-principle and nuclear and radiation safety issues for contractor personnel working at the site. The contractor training is valid only for a determined time and has to be repeated when expired. All contractors and suppliers are regularly audited and evaluated by Fortum to ensure that they can fulfil the regulatory and safety requirements.

Olkiluoto NPP

There is a separate unit for nuclear safety at the Olkiluoto NPP that is independent of the units responsible for operation. TVO also has an independent cross functional safety group that consists of specialists among NPP's own staff and also external expert members that are called in for special topics. TVO has also established documented quality and safety policies for the Olkiluoto NPP.

A periodic safety review regarding Olkiluoto units 1 and 2 was carried out in 2007–2009. In the review, it was concluded that TVO has implemented systematic procedures through which it aims to motivate the personnel to responsible working (e.g. pre-briefing meetings, peer checking etc.). The safety culture development process at the Olkiluoto NPP has been mainly implemented in the manner referred to in Section 28 of the Government Decree 733/2008. The most important development areas are ensuring competence, developing the handling process of safety-related issues, and encouraging safety reporting.

TVO has assessed the safety culture of the Olkiluoto NPP through several methods. The safety culture issues have been regularly discussed in the safety group meetings. Personnel surveys and the peer review method of the World Association of Nuclear Operators (WANO) have also been utilised. TVO has developed a safety culture self-assessment procedure and tools in co-operation with the IAEA. The self-assessment is repeated approximately every third year.

In TVO's performance-based bonus scheme, a part of the bonus is specified based on how well safety culture development measures have been implemented. TVO has taken action to develop the bonus scheme to give higher priority to safety and safety cultural related goals.

TVO has also developed the safety culture training and assessment methods concerning the Olkiluoto unit 3 project and the contributing parties. Assessment method consists of a questionnaire, interviews and analysis of safety observations and non-conformance records. TVO administrates and follows up the competence of contractors that work at the plant regularly or for longer terms. These contractors have to complete the same basic training as NPP's own personnel as appropriate. Basic nuclear and radiation safety training is prerequisite for all persons working at the site. Priority to safety is addressed in the training. TVO regularly audit and evaluate contractors and suppliers to ensure that they can fulfil the regulatory and safety requirements.

Regulatory oversight

STUK has inspected the management systems of both licensees for completion of the updated Guide YVL 1.4. Based on the inspections, development actions needed to fulfil the requirements were identified. STUK has also reviewed the periodic safety review carried out by TVO at the Olkiluoto units 1 and 2 in 2009.

Topics on safety culture are also included in the STUK's periodic inspection programme. In 2008–2009, the inspections contained topics such as personnel resources and competence, training and reward systems. A top level inspection of the periodic inspection programme, "Management and Safety Culture", includes an assessment of safety culture issues, management and leadership. Additionally, safety culture issues are included in quality assurance audits and event analyses. Safety culture related findings from different inspections are discussed in regular meetings in STUK and between the senior management of the plants and the regulatory body.

STUK has done co-operation with VTT Technical Research Centre of Finland on safety culture related inspections, especially recently on safety culture assessments for Olkiluoto unit 3 construction site. Safety culture related seminars have also been arranged together with both VTT and the licensees, and vendors.

Means used by regulatory body in its own activities

Safety is emphasised in the Quality Manuals of STUK as well as in the framework contract between STUK and its technical support organisation VTT Technical Research Centre of Finland. STUK's Quality Policy includes STUK's values that give the highest priority to keeping the radiation exposure of people as low as reasonably achievable and preventing radiation and nuclear accidents. STUK has taken an active role in this area and both developed its own culture and taken the initiative in the assessment of cultures of the licensee organisations.

The periodic inspection programme is established according to STUK's strategic decisions about safety critical areas at NPPs. These areas are covered at least every third year. STUK conducts self-assessments and personnel questionnaires to follow up the internal opinions regarding the priority devoted to different topics of nuclear safety. STUK arranges regularly training for the inspectors and an induction programme is set up for all new recruited inspectors. STUK has added resources to and reorganised the organisation that handles NPP security issues.

In conclusion, Finnish regulations and practices are in compliance with Article 10.

Article 11. Financial and human resources

1. ***Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.***

Financial resources

Nuclear Energy Act defines as a condition for granting a Construction or Operating Licence that the applicant has sufficient financial resources, necessary expertise and, in particular, that the operating organisation and the competence of the operating staff are appropriate. According to the Nuclear Energy Act, the licensee shall also have adequate financial resources to take care of the safety of the plant. In addition, Nuclear Energy Act provides detailed regulations for the financial arrangements for taking care of nuclear waste management. The Act on Third Party Liability provides regulations on financial arrangements for nuclear accidents, taking into account that Finland is a party to the Paris and Brussels conventions.

The financial preconditions are primarily assessed by authorities other than STUK (mainly the Ministry of Employment and the Economy). The financial position and business environment of the licensee also affect the safety of plants, and STUK therefore follows licensees' plans to improve safety of nuclear power plants, as well as organisational reforms, safety research conducted by licensees, the number of employees and the competence of personnel. The annual reports of Fortum Corporation and Teollisuuden Voima Oyj provide financial information on the utilities. Both utilities have annually invested typically about 10–20 M€ for maintaining the plant and improving safety.

A financing system for the costs of future waste management and decommissioning exists to ensure that the producers of nuclear waste bear their full financial liability on the coverage of those costs and that the costs can be covered even in case of insolvency of the waste generator. The pertinent licence-holders submit annually for regulatory review the technical plans and cost calculations on which the liability estimates are based. After confirmation of the financial liabilities, the licensees pay fees to a State controlled fund and provide securities for the liability not yet covered by the funded money. At the end of 2009, the funded money (1 800 million euros) covered most part of whole liability (2 080 million euros). Remaining 280 million euros were to be covered by payment of 88 million euros and securities.

Human resources

The licensee has the prime responsibility for ensuring that all the employees are qualified and authorised to their jobs. The regulatory requirements for human resources are stated in the Nuclear Energy Act (Sections 7 and 20), the Government Decree on the Safety of Nuclear Power Plants (733/2008) and STUK's Guides YVL 1.6 and YVL 1.7. According to Section 30 of the Government Decree 733/2008, significant functions with respect to safety within nuclear power plants must be designated, and training programmes must be prepared for development and maintenance of professional qualifications of the persons working in these positions. Adequate command of the functions in question must also be verified. The Guide YVL 1.6 sets requirements for NPP operator competence, and the Guide YVL 1.7 for training and qualifications of personnel working in functions that are important for plant safety. The YVL Guides concerning human resources are currently being updated. Also other YVL Guides include requirements concerning licensee's qualifications.

Personnel and human resources related issues are included in STUK's periodic and construction inspection programmes at the nuclear power plants. A top level inspection of the periodic inspection programme, "Human Resources and Competence", includes assessment of human resource management, competence development and training programmes. It also covers the licensee's procedures for managing human resources and competence of suppliers, sub-suppliers and other partners participating in functions affecting safety. In 2008–2009, STUK has paid attention especially to work fatigue management and management of working hour accumulation. STUK also participates in examinations of shift personnel, where the operators working in the control rooms show that they are conversant with all salient matters related to plant operation and safety. STUK further approves the appointment of certain key personnel, such as the responsible director and his/her deputies.

Both TVO and Fortum are currently updating their human resource and personnel planning based on STUK's requirements. Human resource planning at the Loviisa NPP is based on a ten-year plan, which is subject to annual management review and updating. STUK has identified a need for human resource development in, for example, quality control and assurance, risk assessment and radiation protection. Recruitment processes have been started at the Loviisa NPP in order to improve the situation.

The training activities and procedures at the Loviisa NPP are currently being changed, with the objective of vesting the line organisation with responsibility for competence development while the training section supports the line organisation with their expertise. Furthermore, the training organisation has been recently strengthened with experts in behavioural sciences.

TVO recruited several new employees during 2008 and 2009 for the Olkiluoto NPP. With these recruitments, TVO has been seeking to prepare for the generation change that is currently in progress in the nuclear industry in Finland. TVO also prepared procedural instructions on strategic human resource planning during 2008. In its inspections, STUK has raised concerns on the number of personnel and the management of working hour accumulation during annual maintenance operations. STUK is under the impression that the workload of certain key persons has increased because TVO deploys its personnel for the needs of both the operational units of Olkiluoto 1 and 2 and the construction site of Olkiluoto unit 3. TVO has trained and instructed managers, supervisors and operating personnel on the importance of work fatigue management.

Following STUK's inspections, the methods for assessing effectiveness of training programmes were developed at TVO during 2008. This includes, for instance, defining the training objectives more clearly. TVO operates a data system designed for competence management that has been systematically developed during the past few years through co-operation between training experts and managers. The methods for ensuring that the new personnel are competent before starting operating independently are under continuous development at the both NPPs operated by Fortum and TVO.

Fortum has under corporate structure own unit for Loviisa NPP Technical Support. Both Fortum and TVO also use external expertise whenever necessary for engineering and technical support functions. Their aim is to sign long-term co-operation agreements providing better preconditions for ensuring sufficient supplier competence. Both utilities provide external personnel introductory training and other training if necessary. They also assess supplier competence regularly and oversight supplier activities.

Ensuring an adequate national supply of experts in nuclear science and technology and high quality research infrastructure is a continuous challenge in Finland because of the retirement of large age groups, ongoing Olkiluoto unit 3 construction project and possible new plant projects. In addition to the measures to maintain and develop the capabilities and amount of professional staff of STUK and the utilities, the similar requirements for maintaining and developing the human resources in the nuclear energy sector apply to VTT Technical Research Centre of Finland, which acts as the main technical support organisation to STUK. In the same way one has to devote appropriate measures to develop the educational resources in technical universities and other high-level universities in Finland.

STUK is participating in the development and organisation of the basic professional training course on nuclear safety, which is a yearly held 5-week training programme for students and staff members of the participating organisations (STUK, the licensees, VTT, Helsinki and Lappeenranta Universities of Technology, Ministry of Employment and the Economy).

In conclusion, Finnish regulations and practices are in compliance with Article 11.

Article 12. Human factors

Each Contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

Regulatory requirements regarding human factors

Human reliability is largely based on good plant design and proper procedures and training. According to Section 6 of the Government Decree on the Safety of Nuclear Power Plants (733/2008), special attention must be paid to the avoidance, detection and correction of any human error during design, construction, operation and maintenance. The possibility of human error shall be taken into account in the design of a nuclear power plant and in the planning of its operation and maintenance, so that human error and deviations from normal plant operations due to human error do not endanger plant safety. The impacts of human error shall be reduced by using various safety principles, including defence-in-depth, redundancy, diversity and separation.

According to Section 19 of the Government Decree 733/2008, the control room of a nuclear power plant must contain equipment that provides information on the operational state of the nuclear reactor and any deviations from normal operation. Furthermore, a nuclear power plant shall contain automatic systems that actuate safety functions whenever required and control and supervise their functioning during operational occurrences and accidents. These automatic systems shall be capable of maintaining the plant in a controlled state long enough to provide the operators with sufficient time to consider and implement the correct actions. The nuclear power plant shall have an emergency control post independent of the control room, and the necessary local control systems for shutting down and cooling the nuclear reactor, and for removing residual heat from the nuclear reactor and spent fuel stored at the plant.

Measures taken by licence holders

Loviisa nuclear power plant

Measures at the Loviisa plant to ensure adequate human performance have been focused on development of operating procedures. Large part of plant's emergency operating procedures (EOPs) are recently modified into flowchart format. These EOPs include symptom based identification which guides operators to event based procedures. Complex accident sequences and core melt accidents lead to symptom based operation. Human redundancy is provided by independent safety engineer. Loviisa plant is equipped with a full scope training simulator which is used for operator training, including accident situations.

Fortum evaluates human reliability as part of the probabilistic risk assessment (PRA). For analysing hidden defects influencing the course of a possible transient or accident, Fortum has evaluated regularly different types of duties performed at the plant. In the analysis such operational and maintenance mistakes have been evaluated which may act as an initiating event of a transient or an accident. Different plant states and duties related to them have been evaluated in detail.

Control actions needed during an accident have been divided in the PRA evaluation into two parts: a diagnosis and actions taken to prevent the accident. Possibilities for mistakes have been studied with the help of a simulator. Plant procedures for emergency situations have been developed and will be further developed, taking also into account the results of PRA. For preventing human errors it is important, that the operating events are carefully evaluated and, if necessary, procedures or the plant is developed to prevent similar mistakes. Fortum has developed the utilisation of operating experiences and does the root cause analyses out of most significant events.

The protection systems of the plant initiate the safety systems automatically when needed so that the operators will have enough time to consider actions according to operating and emergency procedures. Due to the inherent characteristics of the Loviisa plant, the operators will have more time for consideration in a transient situation than usually at other nuclear power plants. The Loviisa units 1 and 2 have their own independent main control rooms where the needed process information is available and control actions can be performed. Alarm signals from the interim spent fuel storage are also available in the Loviisa unit 2 main control room. Process information is presented in the main control room with indicating meters, indicator lights and recorders as well as with the monitors of the process computer system. There are two redundant alarm systems in the main control room. These systems have been realised by using two different techniques, conventional and computer-based techniques. Indicator light fields are in the operator's consoles, and two monitors have been reserved for computer alarms. In addition, data on events and conditions as well as the exceeding of warning and alarm limits are recorded by the alarm printers. The process computer gives process information in an illustrative format for the use of the operators.

In addition to the main control room, the shutdown of the reactor as well as the control and monitoring actions necessary for safety can be performed by means of a so-called emergency control room table, located in the main control room of the other unit. For severe accidents there is a dedicated control room shared by the both units.

The I&C systems are currently being renewed at the Loviisa plant. Human performance is taken into account in the modification. The project began in 2002 with basic conceptual design; implementation begun in 2004 with construction of new buildings to accommodate the new systems. The project is intended to be completed in 2014. The renewal project is discussed in more detail under Article 18.

Olkiluoto nuclear power plant

Basis for safe operation is laid already in design phase. A so-called 30-minute rule has been the design basis for the protection system at the Olkiluoto units 1 and 2. Important protection measures and safety systems start up automatically so, that no actions of operating personnel are needed during the first thirty minutes after the beginning of the operational transient or postulated accident. Proper emergency and transient situation procedures as well as training of those situations reduce the possibility of human errors further.

Olkiluoto units 1 and 2 have their own independent control rooms, where the necessary process information is available, and from where all necessary control measures can be conducted. The alarms covering the interim spent fuel storage are available in the control room of the Olkiluoto unit 1. The technical solutions of the main control rooms are based on the proven control room technology. During the renewal of turbine automation system several new computerised operator workstations and a large screen display system were installed into the main control room. Process information is presented by the indicating measuring equipment installed in the steering desks and panels as well as with several computer display units. Conventional and computer aided alarm systems are used to facilitate the management of main processes and other sub and auxiliary processes. The alarms are indicated primarily by the alarm lamp panels. The parallel alarms received through the computer are seen on the monitors. In addition, the event and state data as well as deviations from warning/alarm limits are printed on the alarm printers. A safety parameter display system (SPDS), which improves the performance capability of the operating personnel in controlling transient and accident situations, is in use at the Olkiluoto plant units. Main control room can now be described as a hybrid control room. All the main control room related modifications are tested at the training simulator, and operators are trained for managing the modified systems prior to the modifications are installed.

Control room personnel have also participated in special Control Room Resource Management training. Similar training is common practice in civil aviation. Later this has been merged with TVO's Human performance 2012 programme.

The control room personnel has participated in studies which evaluate fatigue in their working arrangements and shift patterns. TVO has had a 12 hour shift pattern since 2005. In 2009, TVO conducted a trial of resting in the control room night shift. Based on the experiences, TVO made this as a permanent procedure in Main Control Rooms.

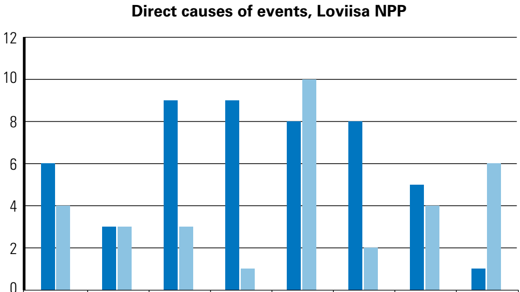
Both Olkiluoto plant units have an emergency control post, from where the reactor can be tripped and where the main parameters of the reactor such as neutron flux, pressure, temperature and water level can be monitored. Cooling the reactor down to a cold state and removal of decay heat can be carried out after the shutdown by using local control posts. The requirement of another, independent emergency control room emerged after the revision of the STUK's Guide YVL 5.5 "Instrumentation systems and components at nuclear facilities" in 2002. TVO is evaluating possibilities to improve and centralise the emergency controls to better apply the present requirements. Modifications are planned to be carried out in connection to the modernisation of reactor protection system in the future.

There are methods for preventing human errors during operation. Main areas to be considered are operation, maintenance and modification projects. Human reliability can be enhanced in every day activities with certain methods. These methods include pre-job-briefing, de-briefing, peer checking, independent verification and clear communication. TVO has trained and introduced these methods in feasible activities. Proper work planning and Permit-to-Work-system in addition to up-to-date procedures are key methods in maintenance related activities to ensure safety during maintenance. Checking and approval requirements are also considered when requalifying systems back into operation. This work is part of a company wide project called "Human Performance 2012" which incorporates also other measures to improve human performance. The aim is to support managers and the personnel in managing human performance to avoid as many human mistakes as possible. TVO has had human factor specialist since 2004.

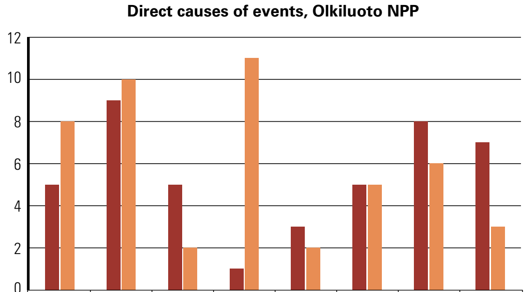
Human Factor issues are taken into account in all events. Lessons learned from the events are taken into account in the corrective action plans and lessons learned are used in internal training and organisational development. TVO has utilised operating experience and results of root cause analyses in the development of human aspects in the operating procedures. Errors related to the maintenance actions have also been examined and measures have been developed to avoid corresponding errors. Fatigue has been identified as an important factor to be managed.

TVO has conducted a probabilistic risk assessment (PRA) where the consequences of human errors have been studied. Latent maintenance and testing errors have been studied in connection with the system analyses related to the PRA. In addition to the human factor experts, experienced staff members from the operating and maintenance personnel have participated in assessing the possibility of errors. The identified error possibilities have been classified into groups according to their importance and the most important ones have been modelled in the PRA study to clarify the risks related to errors. The reliability of operator actions conducted during accident conditions was assessed as a part of the PRA analysis. The diagnostic errors that may be made in connection with accidents have also been assessed. Based on the results of the analyses concerning the human errors, a few additions and modifications have been made on the emergency and operating procedures of the Olkiluoto units 1 and 2.

At the Olkiluoto unit 3, human factors engineering has been part of the design phase. Concept of operation is taken from excisting units and reference plants. Main control room has operational I&C system with operating terminals and large screen displays. This interface can be used in all plant conditions. Additional information can be integrated into this system, e.g. alarm systems and operating procedures. Safety related I&C system has own traditional operating panels which are diverse control method for operational I&C. These safety panels include also hardwired controls which are additional back-up for all I&C systems. Olkiluoto unit 3 has also remote shutdown station. Feasibilty of human factors engineering will be demonstrated in validation studies. Integrated validation will be done at a full scope simulator before plant commissioning.



	2002	2003	2004	2005	2006	2007	2008	2009
LO, Technical	6	3	9	9	8	8	5	1
LO, Human	4	3	3	1	10	2	4	6



	2002	2003	2004	2005	2006	2007	2008	2009
OL, Technical	5	9	5	1	3	5	8	7
OL, Human	8	10	2	11	2	5	6	3

Figure 10. Number of technical and/or human direct causes identified in the event analysis at the Loviisa and Olkiluoto NPPs.

Regulatory oversight

Human factors have to be taken into account in the design and analysed in the failure analyses of plant safety systems and in probabilistic risk assessments. Such analyses have been completed for both Finnish nuclear power plants.

As regards the operation of the facility, the influence of human factors and the respective need for corrective measures are assessed by the licensees and STUK, when evaluating abnormal events and their lessons learnt. Each operating organisation has established a systematic procedure for making event evaluations. Figure 10 shows the share of technical and human related causes for the latest incidents at the Finnish nuclear power plants. E.g. during 2009, Loviisa NPP reported 7 events from which 6 contained human root causes and Olkiluoto NPP reported 10 events from which 3 contained human root causes.

In conclusion, Finnish regulations and practices are in compliance with Article 12.

Article 13. Quality assurance

Each Contracting Party shall take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

Regulatory requirements regarding management systems

According to Section 29 of the Government Decree on the Safety of Nuclear Power Plants (733/2008), the organisations participating in the design, construction, operation and decommissioning of a nuclear power plant are required to employ a management system. The quality management system must cover all functions influencing plant safety, and the licensees are further required to ensure that all their suppliers, sub-suppliers and other partners participating in functions that affect safety adhere to the quality management system. Along with the management system, the Decree sets requirements for the documentation of the lines of management and monitoring of the operations.

STUK's Guide YVL 1.4 sets general requirements for the management system and was updated in 2008. The updated Guide YVL 1.4 adheres to IAEA Safety Standard GS-R-3 on management systems. Requirements for the quality assurance programme during operation are presented in the Guide YVL 1.9 and requirements for quality management of system design in the Guide YVL 2.0. The quality management requirements related to specific technical areas are presented in the corresponding technical guides.

The management systems of the licensees and applicants are subject to approval by STUK. According to the Guide YVL 1.4, any safety-significant revisions to the anagement system must be submitted for approval to STUK, but minor revisions are only submitted for information prior to their use. Implementation of the anagement system is verified by STUK through inspections. The management systems of the main suppliers will also be reviewed and assessed and their implementation will be verified through inspections.

STUK has an own Quality Manual that includes quality policy, description of the quality system, organisation and management, main and supporting working processes and personnel policy. The results of internal audits, self-assessments and international evaluations are used as inputs for the enhancement projects of the Quality Management System at STUK. In addition to STUK's Quality Manual, all main functions of STUK have their own more detailed Quality Manuals.

Measures taken by licence holders

Loviisa nuclear power plant

Fortum's Policy Commitment to Quality in the Nuclear Power Operations was issued in 1999 and it was confirmed in 2001 by the management of Fortum Power and Heat Oy. The development of Loviisa NPP's quality management system is based on the principle of continuous improvement in accordance with the observations and remarks made in quality audits and quality assessments. An evaluation of the plant quality management system against the ISO/DIS 9001 and 9004:2000 standards were made in 2000 by Fortum Engineering. The work continued in 2001–2002 and a similar comparison with IAEA Safety Series No. 50-C/SG-Q was carried out. The environmental management system of the plant was certified in 2002 according to the ISO 14001:1996 standard. During the preparation phase an environmental policy and a new chapter on environmental system were introduced in the Quality Manual.

Fortum has evaluated and prepared development plans for their management system, which STUK has reviewed for implementation of the updated Guide YVL 1.4 requirements. The quality management system of Fortum Power & Heat Oy for the Loviisa NPP complied with the requirements of the Guide YVL 1.4 in many respects, but some deviations still remained. To comply fully with the Guide YVL 1.4, STUK required Fortum to develop and implement a process based operating and management system that will replace the existing function based system stepwise by the end of 2013. Additionally, Fortum was requested to conform to the requirements regarding the purchasing processes, and create procedures for managing changes occurring in the organisation or in the management system.

Olkiluoto nuclear power plant

TVO's quality management system, Activity Based Management System, is described in the Quality Management Manual. It takes into account the requirements from IAEA Safety Series No. 50-C/SG-Q and ISO 9001:2000. Activity Based Management System guides all TVO's operations and provides each staff member with procedures for the safe, economical, high-quality and environmentally friendly generation of electricity. TVO's company-level policies are nuclear safety and quality policy, social responsibility policy, production policy and corporate security policy. The functions and responsibilities of TVO's organisations and personnel are described in detail in the TVO's Administrative Rules, in the Organisational Manual and in the manuals and instructions of individual organisational units. The Administrative Rules have been approved by STUK as a part of the Technical Specifications Document.

For the Olkiluoto unit 3 construction phase STUK has approved "The Quality Manual for Olkiluoto 3 Project". The review of document as well as review of the QM systems of plant vendor and major suppliers is carried out by STUK. STUK has also asked external QM experts' opinions on the QM systems.

TVO has evaluated and prepared development plan for their management system, which STUK has reviewed for implementation of the updated Guide YVL 1.4 requirements. The quality management system of TVO for the Olkiluoto units 1 and 2 mainly complied with the requirements of the Guide YVL 1.4. To fully comply, TVO was required to develop procedures for ensuring that the requirements, interfaces and interactions between processes as well as risks related to operation have been identified in the process development. Further, the requirements for the control of outsourced processes and activities must be included in the management system. Additionally, TVO should describe their procedures for assessing and continuously improving the safety culture. Like Fortum, TVO was also asked to conform to the requirements regarding the purchasing processes, as well as create procedures for managing organisational changes.

TVO's quality management system for Olkiluoto unit 3 construction project was also reviewed against the updated Guide YVL 1.4 requirements. According to STUK's review, the management system of Olkiluoto unit 3 complies with the Guide YVL 1.4 with the only deviation of missing procedures for the regular, independent assessment of the management system.

Regulatory oversight

STUK has reviewed both licensees' quality management systems for implementation of the updated requirements in the Guide YVL 1.4. Both licensees have been required to create and submit development plans to correct all deviations and fully comply with the requirements.

Additionally, a top level inspection of the STUK's periodic inspection programme, "Functioning of the Management System", includes assessment of functioning, development and assessment of the management system as well as assessment of the organisation for quality management. The "Management and Safety Culture" inspection (see Article 10) also contains items concerning management systems. In 2008–2009, the inspections contained issues such as human resource management, competence development and training. STUK has also inspected various quality management related documents, such as rules of procedure, organisation and quality manuals.

Concerning the Olkiluoto unit 3 construction project, STUK has performed quality management and quality assurance inspections as a part of the construction inspection programme. In addition, STUK has participated as an observer in the licensee's and vendor's audits at the subcontractors.

STUK is developing a procedure for collecting observations concerning management system and organisational issues. The aim is to collect and integrate observations from different inspections and oversight practices and make conclusions on the licensee's organisation, management system and safety culture.

In conclusion, Finnish regulations and practices are in compliance with Article 13.

Article 14. Assessment and verification of safety

Each Contracting Party shall take the appropriate steps to ensure that:

i. ***comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of operating experience and significant new safety information, and reviewed under the authority of the regulatory body;***

ii. ***verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.***

Regulatory approach to safety assessment

The Nuclear Energy Decree requires that when applying for a construction licence, the applicant must submit to STUK the following documents: a Preliminary Safety Analysis Report, a design phase Probabilistic Risk Assessment, a proposal for a safety classification document, a description of Quality Management during the construction of the nuclear facility, preliminary plans for the arrangements for security and emergency preparedness, and a plan for arranging the safeguards control. For the operating licence, the applicant must submit to STUK: the Final Safety Analysis Report, the Probabilistic Risk Assessment, the safety classification document, the quality management programme for the operation of the nuclear facility, Operational Limits and Conditions, a programme for periodic inspections, security and emergency plans, a description on administrative rules for safeguards, a programme for radiation monitoring in the environment of the nuclear facility, a description of how safety requirements are met, and a programme for the management of ageing. In addition, the Decree gives STUK a possibility to ask other documents considered necessary for safety demonstration.

Design of the facility is described in the Preliminary (PSAR) and Final (FSAR) Safety Analysis Reports. The reports are submitted to STUK for approval with the applications for Construction and Operating Licences. PSAR/FSAR forms the bases to STUK´s safety assessment which is required before granting the Construction/Operation Licence (see Article 7). According to the Nuclear Energy Decree, FSAR has to be continuously updated, and changes to FSAR are submitted to STUK for approval. Requirements for the plant modification process are presented in the Guide YVL 2.0, "Systems design for nuclear power plants". The main principle in plant modification process is that conceptual design plans and system-specific pre-inspection documents of Safety Class 1, 2 and 3 systems must be submitted to STUK for approval. STUK reviews and approves the modification prior to its implementation at the plant. In connection with a system modification, the Final Safety Analysis Report shall be amended accordingly without delay.

The general design bases for nuclear fuel have been defined in the Guides YVL 1.0 and YVL 6.2. The design objective is that the probability of fuel failure is low during normal operational conditions and anticipated operational transients, and that during a postulated accident the rate of fuel failures remains low and the fuel remains in a coolable state. Detailed requirements for the design, quality management and control, handling, storage and transport of fuel are specified in the Guides YVL 6.2, YVL 6.3, YVL 6.4, YVL 6.5, YVL 6.7 and YVL 6.8.

According to the Nuclear Energy Act, the operating licence is granted for a fixed term. However, legislation has not prescribed the length of the term. The term is proposed by the licensee in the application, and must be justified on the basis of the ageing and planned future operation of the nuclear facility. Particular attention is paid to licensee's processes and activities and planned safety improvements to ensure safety for the estimated duration of operation. The procedure for operating licence renewal is in general the same as in applying for an operating licence for a new nuclear facility. Specific requirements on the documents to be submitted to STUK for the renewal of the operating licence are described in the Guide YVL 1.1 "Regulatory control of safety at nuclear facilities". Renewal of the operating licence always involves a periodic safety review of the facility. If a licence is granted for a significantly longer term than ten years, STUK requires the licensee to carry out a periodic safety review within about ten years of receiving the operating licence or of conducting the previous periodic safety review. For a separate periodic safety review, STUK must be provided with similar safety-related reports as in applying for renewal of the operating licence. Renewal of the operating licence of the Loviisa nuclear power plant took place in 2005–2007 and the periodic safety review of the Olkiluoto units 1 and 2 in 2007–2009 (see Article 6).

The Government Decree on the Safety of Nuclear Power plants (733/2008) requires that nuclear power plant safety and the technical solutions of its safety systems shall be substantiated by using experimental and calculation methods. These include among others analyses of operational occurrences and accidents, strength analyses, failure mode and effect analyses, and probabilistic risk assessments. Analyses shall be maintained and revised if necessary, taking into account operating experience, the results of experimental research, plant modifications and the advancement of calculation methods. The calculation methods employed for demonstrating compliance with safety regulations shall be reliable and well qualified for the purpose. They shall be applied so that the resulting system design bases meet the acceptance criteria with high certainty. Any uncertainty in the results shall be assessed and considered when defining safety margins. STUK's review of these analyses includes independent safety analyses.

Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL 2.2, "Transient and Accident Analyses for Justification of Technical Solutions at Nuclear Power Plants". Requirements for probabilistic risk assessments are given in the Guide YVL 2.8, "Probabilistic safety analysis in safety management of nuclear power plants". Acceptance criteria for the analyses are presented in Guides YVL 6.2 "Design bases and general design criteria for nuclear fuel" and YVL 7.1, "Limitation of public exposure in the environment of and limitation of radioactive releases from a nuclear power plant".

Safety assessment of new nuclear power plants

Three new nuclear power plant units have been under consideration in Finland (see more details of the licensing process under Articles 7 and 17). TVO submitted application for a Decision-in-Principle to the Ministry of Employment and the Economy in 2008, Fennovoima and Fortum in 2009. In addition, two applications by Posiva Oy have been handled for the expansion of the planned capacity of spent fuel repository. The applications for NPP units were accompanied by documents of a total of seven alternative plant designs. The Government made on May 6 2010 positive decisions regarding the applications of TVO and Fennovoima and the Parliament ratified the decision on July 1 2010.

STUK gave the Ministry preliminary safety assessments of all Decision-in-Principle applications in 2009. STUK's preliminary safety assessments consisted of an assessment of the safety of the plant alternatives and the sites as well as of an assessment of the organisations and the quality management of the applicant. The assessments also cover the physical protection and emergency preparedness arrangements, nuclear fuel and nuclear waste management, nuclear liability and non-proliferation.

Most of the plant alternatives reviewed in the STUK's preliminary safety assessments do not meet Finnish safety requirements as such. The nature and the extent of the required modifications vary between the plant alternatives. Some plant alternatives would only require fairly minor modifications; some would require more extensive structural modifications. The required technical solutions are still open for some alternatives.

Site assessment is described in more detail under Article 17.

Deterministic safety assessment

Detailed requirements concerning transient and accident analyses, including sensitivity analyses, are presented in the Guide YVL 2.2, "Transient and Accident Analyses for Justification of Technical Solutions at Nuclear Power Plants".

Fortum submitted with the licence renewal documentation in 2005–2007 the revised Final Safety Analysis Report, including the transient and accident analyses of the Loviisa units 1 and 2. Fortum has revised the analyses taking into account plant modifications implemented at both units as well as new regulatory requirements. The analyses presented in the Safety Analysis Report cover anticipated operational transients, category 1 and 2 accidents, and severe accidents. The analyses cover all operating states and include accident analyses for the storages of spent fuel and reactor waste.

STUK assessed the submitted analyses for the Loviisa NPP and methods applied in the analyses. STUK contracted VTT Technical Research Centre of Finland to carry out independent analyses to verify the results given in the licence renewal documentation and to conduct sensitivity analyses. STUK concluded that the plant behaviour in different transient and accident situations has been analysed comprehensively and that the methods used in the analyses are properly validated to describe the operation of the Loviisa plant.

Accident and transient analyses of the Olkiluoto units 1 and 2, as well as the analysis methods, have been updated and developed throughout the operation of the plant. TVO revised completely the accident and transient analyses in conjunction with the application for the renewal of its operating licence in 1995–1998. The analyses were at that time carried out for nuclear fuel that is no longer being used at the NPP units. For the periodic safety review in 2007–2009, TVO updated the accident analyses using the SVEA-96 Optima 2 as a reference fuel. The plant modifications carried out after the renewal of the operating licence in 1998 were also taken into account in the update. Since renewal of the operating licence, Guides YVL 2.2 and YVL 6.2 have been revised and a requirement regarding analyses of design extension conditions was introduced. When updating its analyses for periodic safety review, TVO has taken into account the new regulation.

The calculation methods used for analysing the plant normal operating conditions, transients and postulated accidents were developed by the supplier of the Olkiluoto plant units. The methods have been qualified to an extent corresponding to a good level from the international perspective. STUK reviewed the updated analyses and the calculation methods used. The conclusion was that the analyses of transients and accidents of the Olkiluoto units 1 and 2 were conducted as referred to in Section 3 of Government Decree 733/2008. However, STUK required updating of the loss of coolant analyses assuming a level of system availability specified in the Guide YVL 2.2. TVO submitted the required updates in 2010.

The preliminary analyses of Olkiluoto unit 3 were presented to STUK in PSAR and the Topical Reports appended to PSAR with application for the construction licence. STUK contracted technical support organisations to carry out independent analyses to verify the results. STUK approved the PSAR of Olkiluoto unit 3 in January 2005 just before the construction licence was granted by the Government. TVO has submitted updated analyses for the Final Safety Analysis Report in 2008–2010. The analyses will be reviewed as a part of the Olkiluoto unit 3 operating licence application.

Probabilistic risk assessment

Regulatory requirements on PRA

STUK required in 1984 that the Finnish utilities Fortum (former Imatran Voima Oy) and TVO shall make extensive probabilistic risk assessments (PRA) for the Loviisa and Olkiluoto nuclear power plants. The objective of the study was to determine the plant-specific risk topographies of the essential accident sequences. Another important objective was to enhance the plant personnel's understanding of the plant and its behaviour in different situations. Therefore STUK also required that the PRAs are performed mainly by the utility personnel and external consultants are used only for special topics.

In 1987 STUK published the Regulatory Guide YVL 2.8 on PRA. The Guide was updated in 1996 and 2003. Currently the Guide requires a full-scope (including internal events, fires, floods, seismic events, harsh weather and other external events)

PRA for power operation and low-power and shutdown states. PRA shall cover the probability of core damage (Level 1) and large release of radioactive substances (Level 2). PRA shall be updated continuously to reflect plant and procedure modifications and changes in reliability data (Living PRA).

Guide YVL 2.8 includes the following probabilistic safety goals:

- Core damage frequency less than $1 \cdot 10^{-5}$/year
- Large radioactive release (> 100 TBq Cs-137) frequency less than $5 \cdot 10^{-7}$/year.

These safety goals apply as such to new plant units. For operating units, instead of the numerical safety goals, the SAHARA (safety as high as reasonably achievable) principle and the principle of continuous improvement are applied.

Guide YVL 2.8 also includes requirements on several risk-informed applications, such as analysis of plant modifications, risk-informed in-service inspections and testing, development of emergency operating procedures and training programmes and review of safety classification and Operational Limits and Conditions.

For a new plant unit, a preliminary PRA covering Levels 1 and 2 shall be submitted to STUK for the review of the construction licence application (design phase PRA) and the updated and complement PRA (Levels 1 and 2) shall be submitted for the review of the operating licence application.

PRA's computer models shall be made available to STUK. STUK uses PRA routinely to support its decision making, for example, in review of plant modifications and applications for exemption from Operational Limits and Conditions and in analysis of operating events.

Main developments in risk informed regulation during the reporting period

During the reporting period the role of risk informed regulation and safety management has been further strengthened by STUK and the licensees. The following activities can be given as examples of the increased role of risk informed methods:

- Both licensees, TVO and Fortum, have developed Risk-Informed In-Service Inspection programmes for the operating units. Fortum has introduced the programme in 2009 and TVO plans to introduce it in 2011.
- TVO and Fortum have applied PRA in support of the review of safety classification of the operating units.
- TVO and Fortum have introduced a method for risk informed review and development of Operational Limits and Conditions, especially allowable outage times and testing intervals. TVO has already implemented the updated allowable outage times and test intervals. At Fortum the work is in progress.
- Olkiluoto unit 3 PRA is being finalised and risk informed applications have been used in the design of the unit and the risk informed applications for the operating phase are under development in accordance with the Guide YVL 2.8. PRA is also used in the planning of commissioning testing programmes.
- Risk informed methods have been used to support ageing management, for example, trend analysis of failure data. In connection with the life extension of Loviisa unit 2 reactor pressure vessel, the probabilistic analysis of pressurised thermal shock has been updated to evaluate the safety significance of radiation induced embrittlement of weld seams.

The use of PRA in several well-established applications has been continued and the methods have been further refined. STUK has continued the extension of the PRA computer code system developed at STUK. The software is used in the review of the PRAs submitted by the licensees and in support of risk informed decision making at STUK.

In addition to the risk informed applications based on regulatory requirements, the licensees use PRA in applications supporting their operating activities, for example availability analysis and risk centred maintenance.

Probabilistic risk assessment of the Loviisa units 1 and 2

Fortum provided STUK with Level 1 PRA in 1989. Since 1990 Fortum has extended PRA by analysing risks related to fires, floods, earthquakes, severe weather conditions and outages, as well as by conducting Level 2 PRA. Plant modifications have been carried out continuously at the Loviisa NPP, including safety system improvements, fire safety improvements, implementation of Severe Accident Management systems and a major modernisation

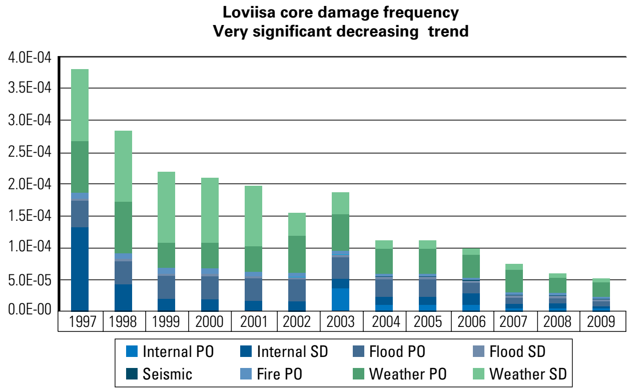


Figure 11 Loviisa core melt frequency in 1997–2009. The increase in the core damage frequency in 2003 was due to extension of the PRA scope with non-seismic external events during shutdown states. The preliminary conservative analyses showed relatively high risk due to exceptionally high outside air temperature and oil spills in the Gulf of Finland in cold shutdown states. Later the risk was decreased due to plant modifications and more realistic analyses.

programme in mid 1990's (see Annex 2). By means of these modifications risks have been decreased and the risk topography of the plant has been balanced. Technical solutions of the modifications have also been often justified with PRA.

The development of the core damage frequency since 1997 is shown in Figure 11. At the end of year 2009 the calculated estimate for the total probability of reactor core damage was about $6.0 \cdot 10^{-5}$ per reactor year. The contribution to the core damage frequency from different groups of initiating events is shown in Figure 12. The Loviisa plant has allmost full scope PRA covering Levels 1 and 2, but some parts still need refinement of analysis, for example, the detailed fire PRA for shutdown states will be performed when the changes in cable routes due to the I&C renewal are known.

Fortum has also provided STUK with the Level 2 PRA in which the integrity of the containment and the release of radioactive materials from the

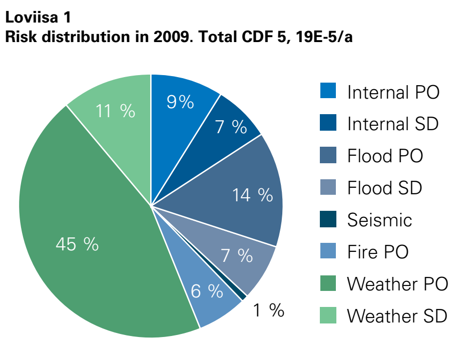


Figure 12. Loviisa core damage frequency in 2009 by initiating event types. The most significant internal initiating events at full power (power operation, PO) are the small interfacing LOCAs and the loss of instrumentation room ventilation. At shutdown (SD) the most significant internal initiating events are drop of heavy loads and reactivity accident due to boron dilution.

plant to the environment are evaluated. It was estimated that the total probability of a large release to the environment is about $2.7 \cdot 10^{-5}$ per year. The following modifications of the Loviisa plant made to implement the severe accident management strategy have been included in the estimate: the external cooling of the reactor pressure vessel, the measures aimed at preventing such loading situations which break the reactor cavity, the improved control of hydrogen and the new procedures for severe accident management. The estimate for a large release includes a detailed Level 2 PRA study for internal events, floods and severe weather conditions at power states, whereas the remaining areas (fire, seismic and outages) are based on a rough estimate on the consequences of the accident sequences from Level 1 analyses. The probability of large release will be decreased to $1.8 \cdot 10^{-5}$/year by the year 2012 when the planned plant modifications have been implemented. The modifications include installation of alarming boron analysers to reduce the risk of reactivity accidents in shutdown states, changes allowing improved hoisting routes to reduce the risk due to the drop of heavy loads, modernisation of the I&C system and improvements of the control rod cooling system to avoid leaks causing consequential damage in instrumentation rooms.

The results of STUK's review show that Fortum has applied in its analyses commonly accepted methods in modelling transient and accident situations of the plant and in collecting and analysing reliability data. The reviews also show that the assessments provide an adequate basis for risk informed decision making.

PRA has been used by the licensee in the risk-informed applications required by the Guide

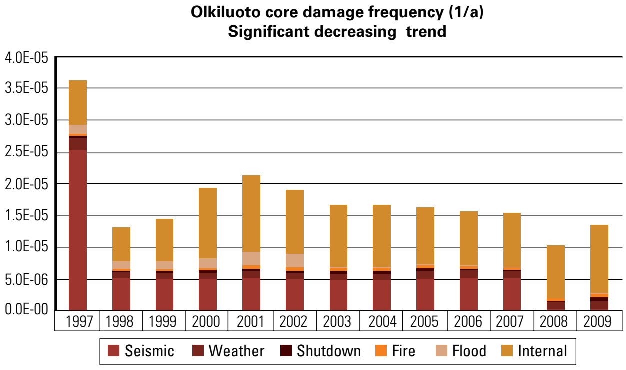


Figure 13. Development of Olkiluoto units 1 and 2 core damage frequency in 1997–2009. The large decrease of the seismic risk in 1998 is due to improvement of the anchorage and supports of batteries and some electronic equipment. Originally they were not designed against any horizontal loads. The decrease in seismic risk in 2009 is due to plant modifications allowing improved handling of spurious activation of isolations due to relay chatter. The risk increase in 2000 is due to decreased time for creating a diesel generator cross connection between units after a total loss of AC power at one unit. The decrease of the available time was due to power uprate in 1998, but it was found out in more detailed thermal hydraulic analyses in 2000. The risk increase in 2009 is due to a more detailed analysis of the capacity of decay heat removal by diverse systems.

YVL 2.8, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times). The Loviisa NPP has also introduced a Risk-Informed In-Service Inspection programme for piping. The number of inspections was increased but the focus shifted from high safety classes to lower safety classes. This shift is due to the fact that some lower safety class piping has relatively large risk significance as they belong to vital support systems or the leaks of lower class pipelines may lead to consequential damage to safety systems. The radiation doses to inspection personnel will decrease as a result of the new inspection programme.

Probabilistic risk assessment of the Olkiluoto NPP

TVO submitted to STUK the first version of Level 1 PRA in 1989. Since then, the PRA has been updated several times and the scope has been extended. TVO has now practically full-scope PRA covering levels 1 and 2 for full power operation and for low power and shutdown states.

Core damage frequency since 1997 is shown in Figure 13. Plant modifications have been carried out continuously at the Olkiluoto plant, including backfitting with severe accident management systems and power uprate and modernisation in the 1990's (see Annex 2).

At the end of 2009 the overall core damage frequency of Olkiluoto units 1 and 2 is approximately $1.3{\cdot}10^{-5}$ per reactor year, including all operating states and all groups of initiating events. The contribution to core damage frequency from different groups of initiating events is shown in Figure 14.

In 1996, TVO submitted to STUK the Level 2 PRA. The analysis was updated during 1997 and 2003. According to the living PRA model in 2004 the frequency of the large release to the environment (>100 TBq Cs-137) was $6{\cdot}10^{-6}$ per reactor year, which was approximately one third of the core damage frequency.

The regulatory review done by STUK showed that, in its analyses, TVO has applied generally approved methods in modelling the transient and accident situations of the plant as well as in obtaining and analysing the reliability data.

TVO has used PRA in the risk-informed applications required by the Guide YVL 2.8, for example in evaluation of plant modifications, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, and optimisation of Operational Limits and Conditions (allowable outage times).

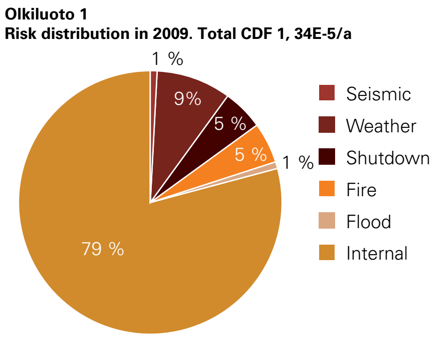


Figure 14. Olkiluoto units 1 and 2 core damage frequency in 2009 by initiating event groups. The most significant internal initiating events at full power are the loss of off-site power and loss of feedwater.

Probabilistic risk assessment of Olkiluoto unit 3

The vendor of Olkiluoto unit 3 conducted a design phase PRA, which TVO submitted in 2004 to STUK for the review of the construction licence application as required by the Nuclear Energy Decree. The design phase PRA includes analysis of internal initiating events, internal hazards and external hazards for power operation and refuelling outage. STUK approved the Olkiluoto 3 PRA for the construction licence in January 2005. The PRA of Olkiluoto 3 has been continuously updated by the plant vendor during the construction phase and STUK has closely followed the completion of the PRA.

PRA has been used by TVO and plant vendor in the risk-informed applications required by the Guide YVL 2.8, for example in evaluation of system design, review of safety classification, development of Risk-Informed In-Service Inspection programme, optimisation of testing intervals, optimisation of Operational Limits and Conditions (allowable outage times), and planning of plant commissioning tests.

Verification of safety

Verification programmes

Government Decree 733/2008 includes several requirements which concern the verification of the physical state of a nuclear power plant. For instance, in all activities affecting the plant operation and the availability of components, a systematic approach shall be applied for ensuring the operators' continuous awareness of the state of the plant and its components. The reliable operation of systems and components shall be ensured by adequate maintenance as well as by regular in-service inspections and periodical tests. General requirements on verification programmes and procedures are provided in the YVL Guides (e.g. Guide YVL 1.8, YVL 1.9, YVL 3.0, YVL 3.8).

Main programmes used for verification of the state of a nuclear power plant are

- periodic testing according to the Operational Limits and Conditions
- preventive and predictive maintenance programme
- in-service inspection programme
- periodic inspections of pressure equipment and piping
- surveillance programme of reactor pressure vessel material
- programmes for evaluating the ageing of components and materials.

Activities for verifying the physical state of a power plant are carried out in connection with normal daily routines and with scheduled inspections, testing, preventive maintenance etc. Activities are performed by the licensee and in the case of certain inspections by contractors approved separately. Detailed programmes and procedures are established and approved by the licensee. They are also reviewed and, when needed, approved by STUK. The results of tests and inspections are documented in a systematic way and used through a feedback process to further develop the programmes. The Operational Limits and Conditions are approved by STUK. In general, the role of STUK is to verify that the licensees follow the obligations imposed on them and carry out all activities scheduled in verification programmes.

Comprehensive evaluations related to the state and operation of the Loviisa and Olkiluoto plants were carried out in the periodic safety reviews by Fortum in 2005–2007 and TVO in 2007–2009. These activities were controlled by STUK.

Inspection qualification

According to international experience and the Guide YVL 3.8, STUK has recognised the qualification of non-destructive testing systems and procedures as an issue of high importance. This issue requires high priority at both nuclear power plants. The implementation of qualified NDT systems has been started in 1990's.

General requirements on inspection qualification are provided in the Guide YVL 3.8. The document "European methodology for qualification" drawn up by the European Network for Inspection and Qualification (ENIQ) shall be used as the minimum requirement level for qualification of inspection systems to be used in in-service inspection, and it shall be complemented by the ENIQ Recommended Practices. In the content of licensees' guidelines published by the qualification body, the requirements presented in the Guide YVL 3.8, in the European Methodology for Qualification (EUR 17299) and in its recommendations have been taken into account.

The licensees Fortum and TVO have established the Steering Committee for Qualification and nominate its members on annual basis. The Steering Committee for Qualification is guiding and supervising the practical qualification work with the help of a separate Technical Support Group nominated and supervised by the Steering Committee.

Based on a contract with the licensees, Inspecta Certification is nominated as the qualification body for qualification management, implementation, control and assessment as well as the issuing of qualification certificates in Finland. The Finnish qualification body is a qualification body of type 1, which is an independent third party organisation as defined by ENIQ Recommended Practice 7. When needed Inspecta Certification uses also experts outside of its own organisation for individual qualifications.

Most of the qualifications have already been performed and approved by STUK.

STUK ordered in 2009 an assessment of the current qualification activities in Finland from an independent expert organisation. The purpose was to assess whether Finnish inspection qualification practice leads to reliable and effective in-service inspection of safety critical components. Review was performed in two parts: 1) review of the inspection qualification system as specified in the Guide YVL 3.8 and the national qualification guideline documents issued by the qualification body and 2) review of the inspection qualification practices. As a conclusion of the assessment it was reported that the qualification system meets the Finnish requirements, is effective and provides confidence in the inspections of safety critical components.

In-service inspections

The condition of the pressure-retaining components of the Loviisa and Olkiluoto NPPs is ensured with regular in-service inspections. The components of the primary circuit are inspected by means of non-destructive examination methods. These regularly repeated examinations are carried out during outages according to the Guide YVL 3.8. The results of the in-service inspections are compared with the results of the previous inspections and of the pre-service inspections which have been carried out before the commissioning.

The in-service inspection plans are submitted to STUK for approval before each individual in-service inspection. Programmes and related inspection procedures are changed when necessary, taking into account the development of requirements and standards in the field, the advancement of examination techniques and inspection experiences as well as operating experiences in Finland and abroad.

Guide YVL 3.8 and the latest revisions of the ASME Code, Section XI are applied as approval bases for the in-service inspection programmes and procedures. ASME Code, Section XI, Appendix R and ENIQ European Framework Document for Risk-informed In-service Inspection are used as approval bases for the risk-informed in-service inspection programmes.

The reliability of the non-destructive examination methods for the primary circuit piping and components has been essentially improved after the commissioning of the both Loviisa and Olkiluoto NPPs. Guide YVL 3.8 calls for the qualification of the entire NDT-system; equipment, software, procedures and personnel. Most of the inspection systems are already qualified at the both plants. STUK follows the development and implementation of the plans.

A risk-informed inspection programme has been introduced and approved by STUK at Loviisa unit 1 for the inservice inspections of safety-critical pipelines. The deployment of risk-informed inspection methods for targeting inspections has been developed in Finland by STUK, Fortum, FNS (Fortum Nuclear Services), TVO and VTT. The objective of risk-informed in-service inspection programmes is to allocate inspection resources to the targets that are most critical from the point of view of risk. Using this approach, it is possible to ensure that the current inspection objects are well-justified, identify new objects and omit certain less safety-critical objects from the existing inspection programme. According to experts' view, the programme is the most extensive risk-informed in-service inspection programme so far implemented in Europe.

The development of a risk-informed inspection programme for Loviisa unit 2 has been started. The length of the inspection period of the regular inspections (e.g. ASME Code, Section XI) is normally ten years. Inspection programmes have been complemented with additional inspections as regards the reactor pressure vessel and the primary circuit piping, and the length of the inspection period of the reactor pressure vessel has been reduced to eight years. The length of the inspection period of the objects susceptible to thermal fatigue is typically three years.

At the Olkiluoto plant, attempts have been made to focus the inspections on areas where faults are most likely to emerge. These include, for example, items susceptible to fatigue due to temperature variations or items susceptible to stress corrosion cracking. The selection of inspection items is under continuous development. For this purpose, a risk-informed in-service inspection procedure is being developed for the Olkiluoto units 1 and 2. Inspections and inspection schedules will be optimised on the basis of risk-informed methods when the next inspection interval programmes are drawn up.

The frequency of the non-destructive examinations performed at regular intervals is usually ten years at the Olkiluoto NPP. The inspection frequency for items susceptible to thermal fatigue is three years, and the inspection frequency for items susceptible to stress corrosion cracking is three or five years.

In addition to the inspections mentioned above, physical inspections concerning the condition and reliability of pressure equipment are carried out as regular pressure equipment inspections according to the Finnish pressure equipment legislation. Such inspections are a full inspection, an internal inspection and an operational inspection. These inspections include non-destructive examinations as well as pressure and tightness tests. The inspections of piping have been defined in the system-specific monitoring programmes. These periodic inspections are dealt with in the Guides YVL 3.0, YVL 3.3, YVL 5.3, and YVL 5.7. The periodic inspection programmes of the Loviisa and Olkiluoto NPPs fulfil the requirements of YVL Guides, as regards the number and techniques of inspections.

Ageing management

According to the Government Decree (733/2008), the design and construction of a nuclear power plant shall include provision for the ageing of systems, structures and components (SSCs) important to safety. Their condition shall be monitored to ensure operability and conformity in design-basis conditions. The needed replacements, repairs and modifications, shall be carried out in a systematic manner.

The regulatory oversight of ageing in operating plants focuses on operating licence renewals and Periodic Safety Reviews (PSRs) where the conformance to the relevant Government Decrees and YVL Guides, including experiences with ageing and its management, is investigated. STUK's findings from other regulatory control practices, particularly the periodic inspection programme, are used as verification. The periodic inspections are done on plant site according to annual planning and tackle both the technical aspects of each discipline and the process of ageing management. STUK also receives annual reports from each nuclear power plant unit on ageing management activities within each technical discipline.

Ageing management at the Loviisa NPP

Radiation embrittlement of the reactor pressure vessel (RPV) and the related surveillance and mitigation actions dominated the ageing management in Loviisa NPP since the early years of operation. This was more relevant to Loviisa unit 1 whose girth weld at the level of the reactor core has a higher content of impurities. In 1996, the brittle weld joint of the Loviisa 1 reactor pressure vessel was heat-treated to improve the ductility properties of the welding material. In this connection the reactor pressure vessel was subject to thorough non-destructive tests. Embrittlement rate has been re-assessed based on the new surveillance programme representing the critical weld. For both units, deterministic and probabilistic safety analyses and associated thermal hydraulic and fracture mechanics studies have been done in a few years' periods to justify continued service of the RPV. For Loviisa unit 1, the latest analyses are valid until 2012 and for Loviisa 2 the analyses are updated in 2010. Fortum's application to extend the operation of the Loviisa unit 2 RPV until the end of 2030, i.e., to the end of the plant unit's operating licence is presently under STUK's review.

In the mid-1990's, Fortum implemented their systematic plant-wide ageing management programme. The SSCs are assigned to categories A through D based on their technical and economical replaceability. SSC failures in category A would limit plant lifetime and thus deserve a part-assembly-wise break-down of ageing related remedies.

Category A comprises the main primary components. Data indicative of plant status and trends are collected with operation, maintenance and inspection IT systems, R&D activities and via experience exchange. The consequent ratings of operability, remaining service life and necessary actions for each SSC are stored on the plant database.

In 2006 the operating utility Fortum submitted to the Government an application to continue the operation of Loviisa units 1 and 2 until the end of 2027 and 2030, respectively, meaning a 20-year extension to the original design lifetime. Among the ageing-related justification were the main fatigue analyses, updated to cover the whole 50 years' life span with consideration of the environmental effects. Documents on In-Service Inspection Summary Programme, Ageing Management Programme Principles and Implementation, and SSC Status and Service Life Extensibility were also submitted. For electrical and I&C components it was noted that massive projects are underway to replace cables in containment due to its detected considerable ambient temperature rise, and for plant-wide replacing of obsolete protection and plant I&C systems and components. In its review, STUK made a general point that the state-of-the-art permitted a quantitative life-time evaluation only in case of ageing by fatigue. However, other potential mechanisms have been identified and resources are in place to monitor, inspect, mitigate and repair as needed. The operating organisation has also strong technical support which has convincingly resolved forthcoming ageing issues in the past, and the history records are well preserved. The Government granted the applied operating licences on condition that two PSRs are undertaken during the licence period.

Ageing management at the Olkiluoto NPP

The ageing management activities at the Olkiluoto units 1 and 2 arose from wide-spread indications of inter-granular stress corrosion cracking (IGSCC) in reactor auxiliary system piping. Early replacement of entire piping systems, achievable with modest doses to maintenance staff, considerably mitigated IGSCC and led the way to the utility's strategy of seeing to the critical SSCs so that a remaining plant life-time of 40 years (design life-time) could be always demonstrated.

Since 1991, the AGE Group, with assistance of several technical discipline related expert groups, has taken care of these activities by gathering information of possibly needed future actions from several sources and by preparing and updating a table of recommended major modifications, replacements, repairs and overhauls. The modernisation and power uprating of the Olkiluoto units 1 and 2 by 16% in 1994–1996 evolved from these recommendations and was completely carried out by the utility's technical support organisation residing on plant site. The associated significant renewal campaigns of obsolete electrical and instrumentation systems and components largely contributed to current 20-year operating licence periods terminating in 2018. Efforts to enhance the reliability and good performance of the plant components, and to ensure the spare part and support service availability have continued until recent years. The major foreseeable modifications until decommissioning have been identified.

Systematic maintenance planning is an integral part of ageing management at the Olkiluoto units 1 and 2. Nominated owners of equipment groups, characterised by a common type or location, analyse the entire maintenance programme and its experiences, and assist in selection of the most effective maintenance works. Annual findings from each equipment group are stored into a relational data base on the plant computer.

STUK reviewed TVO's clarification on the actual condition and ageing implications of the main SSCs in connection to the Periodic Safety Review (PSR) carried out in 2007–2009. Supporting assessment has been done in several periodical inspections on plant site. The main components were generally found to be in good condition, but the appearance of IGSCC in Nickel-based alloys could not be excluded and it possibly explains an indication reported from the safe-end weld of the main feedwater nozzle, made from Alloy 182. The PSR also referred to a completed pilot project for updating fatigue analyses of selected systems to incorporate the environmental effect as required in the implementation process of the Guide YVL 3.5. Based on recommendations from expert consultancy of VTT Technical Research Centre of Finland, more refined modelling is employed now that the utility is renewing all fatigue analyses to justify a prospective re-licensing of the Olkiluoto units 1 and 2 for an operating life of 60 years.

At the Olkiluoto unit 3, the ageing management is taken into account at the design phase. The most severe operating conditions and long-term influences, under which an individual component is expected to serve as a part of a process system, are used to determine the design basis requirements for that component. With known design basis requirements and defined life times of SSCs, their materials, fabrication and other ageing management related issues are specified accordingly. This includes precautions against foreseeable degradation mechanisms with state-of-the art technology, and provision for inspections, overhauls, testing and replacements as needed while respecting the ALARA principle. The anticipated life-span of the main technologies and independence from single technologies are particularly considered in I&C system and somponent design. The design and fabrication of SSCs are verified with qualified analyses, inspections and testing, overseen by STUK, in order to demonstrate fulfillment of quality and performance requirements set by the design specifications. During Olkiluoto unit 3 operation, the ageing of SSCs and retaining the design margins will be managed by dedicated programmes and monitoring tools, and by in-service inspections to whose planning risk-informed methods are applied.

In conclusion, Finnish regulations and practices are in compliance with Article 14.

Article 15. Radiation protection

Each contracting Party shall take the appropriate steps to ensure that in all operational states the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed prescribed national dose limits.

Regulatory requirements regarding radiation protection

The main regulations governing radiation protection of Nuclear Power Plant operation are the Radiation Act (592/1991), Radiation Decree (1512/1991), Government Decree for Nuclear Safety of NPPs (733/2008) and YVL Guides, Part 7 (12 guides). Radiation Decree stipulates that the effective dose caused to a worker shall not exceed an average of 20 millisieverts (mSv) per year in any five years period, nor 50 mSv in any single year. The limit for the annual dose of an individual in the population, arising from the normal operation of a nuclear power plant, is 0.1 mSv. Based on this, STUK shall upon application confirm the release limits for radioactive materials during the normal operation of a nuclear power plant. ALARA requirement is issued in the Radiation Act and more in detail implementation requirements are given in the YVL Guides both for NPP workers and release abatement. During 2007–2009 no changes in the Guides as regards radiation protection were made because the guides were well up-to-date after revision mainly in early 2000.

Radiation doses of NPP workers

There exists an ALARA programme for workers at the Loviisa NPP updated in 2009. It includes main objectives as the continuous improvement in the collective dose indicator trend: decreasing of a four years average, now being at 0.6 manSv/reactor unit/year. Important measures are e.g. minimisation of antimony 122 and 124 content in primary cooling water and optimised use of additional shielding in the primary coolant circuit area during outages. ALARA programme includes also a goal that no employee at the plant should receive a radiation dose exceeding 15 mSv per year. As a plant modification, rearrangement of controlled area activities for decontamination and operational waste management is underway, to be commissioned in 2010–2011.

TVO's ALARA programme for the Olkiluoto NPP contains a compilation of major objectives and procedures regarding the radiation protection and reduction of doses of employees. The ALARA programme is included in TVO's radiation protection manual, which is regularly updated. The ALARA programme includes the goals that collective dose should not exceed 1 manSv for two reactor units in a normal year (1.5 manSv when major additional maintenance is needed) and no employee at the plant should receive a radiation dose exceeding 10 mSv per year.

TVO conducted an independent assessment for its periodic safety review in 2008, comparing the operating experience of radiation protection of workers at Olkiluoto plant units and at similar type of Swedish BWRs. The results indicate that the standards and goals of radiation protection are

Table 1. Radiation doses of workers at the Loviisa NPP in 2007–2009.

Year	Collective dose [manSv]	Maximum individual dose [mSv]	Average dose*) [mSv]
2007	0.72	9.8	1.42
2008	1.56	13.5	2.28
2009	0.75	8.5	1.47

*) calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

Table 2. Radiation doses of workers at the Olkiluoto NPP in 2007–2009.

Year	Collective dose [manSv]	Maximum individual dose [mSv]	Average dose*) [mSv]
2007	1.18	9.4	1.04
2008	0.94	8.1	0.92
2009	1.19	9.9	0.99

*) calculated by using the registered radiation doses, which are ≥ 0.1 mSv/month.

comparable at all the plants surveyed. However, some procedural differences do exist. For example, regarding radiation sources, the primary coolant at plant units in Olkiluoto have, from time to time, contained more antimony than the Swedish BWR plants. Consequently, TVO has replaced antimony-containing components in the primary circuit with new ones with low antimony content. The reduction in moisture of primary steam with the equipment upgrades (new steam dryers) during 2005–2007 at the Olkiluoto NPP substantially reduced the radiation dose rates at the turbine plant.

The risk-informed procedure will be deployed to in-service material inspections in piping and welding for the first time in outages 2011. This will also contribute towards reducing the amount of work carried out in most active areas, thus reducing the radiation exposure of employees.

The radiation dose statistics of the workers are presented for the Loviisa and Olkiluoto nuclear power plants in Tables 1 and 2 and Figures 15 and 16. The individual radiation doses have remained fairly under the set annual and five years dose limits. The maximum combined dose of a Finnish worker at the NPPs for a single year during 2007–2009 was 13.5 mSv. For a 5 years period

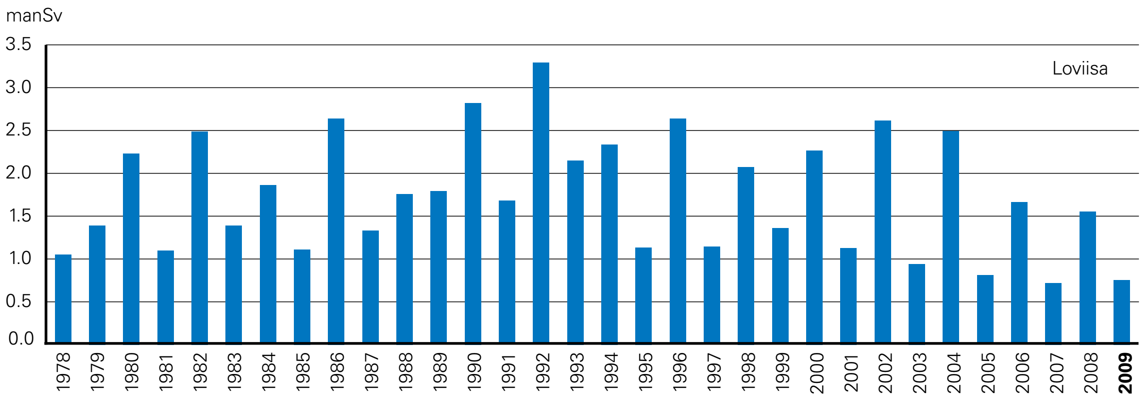


Figure 15. Collective occupational doses at the Loviisa nuclear power plant.

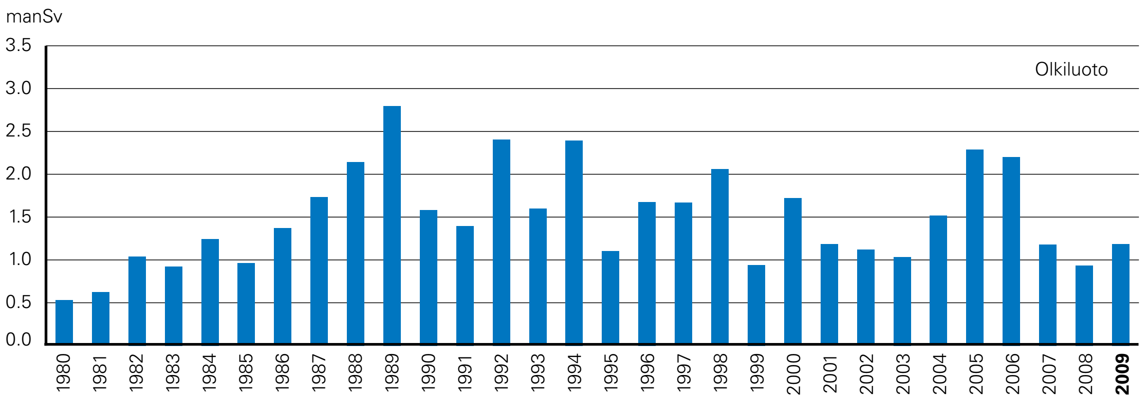


Figure 16. Collective occupational doses at the Olkiluoto nuclear power plant.

Table 3. Radioactive effluents from the Loviisa NPP. The proportion of the release limit is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2007	5.50E+12 (0.03%)	7.34E+05 (0.0003%)	1.12E+08	3.54E+08 (0.04%)
2008	5.51E+12 (0.03%)	1.68E+06 (0.0008%)	8.18E+07	2.90E+08 (0.03%)
2009	7.95E+12 (0.04%)	2.63E+07 (0.01%)	1.22E+08	1.79E+09 (0.2%)

Table 4. Radioactive effluents from the Olkiluoto NPP. The proportion of the release limit is given in parenthesis.

Year	Airborne effluents			Liquid effluents excluding tritium [Bq]
	Noble gases Kr-87 ekv. [Bq]	Iodine I-131 ekv. [Bq]	Aerosols [Bq]	
2007	1.13E+11 (0.0006%)	1.48E+07 (0.01%)	3.01E+07	5.66E+08 (0.2 %)
2008	below detection limit	1.50E+06 (0.001%)	1.76E+07	3.43E+08 (0.1 %)
2009	below detection limit	1.06E+05 (0.0001%)	2.93E+07	2.01E+08 (0.07 %)

2005–2009, the maximum dose was 54.6 mSv and was also received by a person working both at the Loviisa and Olkiluoto nuclear power plants.

In international comparison (e.g. the ISOE radiation dose database of the NEA, the Nuclear Energy Association of the OECD countries), the Olkiluoto units 1 and 2 have been among the best boiling water reactors when comparing both individual and collective radiation doses. The long-term planning of annual maintenance operations has made it possible to keep their duration short, which usually reduces the amount of work carried out and hence also the exposure to radiation. Loviisa NPP has managed to decrease their collective dose and is well in comparison with different type of PWRs.

Radioactive effluents

STUK confirms upon the licensee's application the release limits for radioactive materials during the normal operation of a nuclear power plant. Operational Limits and Conditions have stringer requirements which apply for the radioactive substances of primary coolant (fuel integrity), thus practically preventing releases. Fuel rods at the Olkiluoto and Loviisa nuclear power plants have very low failure rates. Both nuclear power plants have efficiently implemented measures to reduce the releases of radioactive substances into the environment.

The radioactive effluents from the plants in 2007–2009 are shown in Tables 3 and 4. Radioactive releases into the environment from the Finnish nuclear power plants have been well below authorised limits (for important nuclides and pathways, of the order of 0.01% to 0.1% of set values based on the requirements). Calculated radiation exposures to the individual of the critical group living in the environment of the nuclear power plants are shown in Figure 17.

STUK has requested reports from Fortum and TVO on the implementation of the Guide YVL 7.1 concerning the potential solutions (Best Available Techniques, BAT) for further reduction of the radioactive releases from the Loviisa and Olkiluoto NPPs. Fortum has developed caesium removal technology from liquid releases which is in successful operation. The utility has still some comparison with VVER reactor R & D issues and evaluation of their own developments underway, to be reported in 2011. TVO and the Olkiluoto plant had previously carried out improvements on water treatment and purification of discharge waters, and no new solutions have been presented now. TVO had also an independent assessment, comparing the emissions and operating experience in the Olkiluoto plant units and in equivalent Swedish BWRs. The results indicate that the standard of radiation protection is also in this respect at least the same at the reference plant units surveyed.

Environmental radiation monitoring

STUK has approved the operating programme for environmental radiation monitoring in the surroundings of the Loviisa and Olkiluoto NPPs for 2008–2011. The changes in the programme compared with the previous one were related to, inter alia, the use of reference samples, measurements of the water treatment plant sludge and the interpretation of measurement results on carbon-14 nuclides.

An outside contracted laboratory collects and analyses about 300 samples (air, fallout, sediment, indicator organisms, milk, etc.) per year from the environment of each NPP. Very small quantities of radioactive substances of local origin were detected in 2007–2009 on some samples from the environment of each nuclear power plant. Concentrations of the radioactive substances were very low, and effects on the public are insignificant.

Regulatory oversight

On the basis of documents submitted by the operators, STUK approved in 2007 the use of the dosimetry service of the Loviisa nuclear power plant and the Olkiluoto nuclear power plant until 2011. As appropriate, the approval also covers the agreement between the operator and the outsourced services sold by Doseco company, responsible for routine dosimetry at the Olkiluoto NPP. STUK has audited also the dose monitoring service at Doseco Oy.

The dosimeters used for measuring the occupational radiation doses of Loviisa and Olkiluoto plants have underwent annual tests of STUK regularly with acceptable results. These tests comprise irradiating a random sample of dosimeters at STUK's radiation standard laboratory and determination of the doses at the power plant (blind test).

STUK carries out yearly radiation protection inspections on-site according to the periodic inspection programme, e.g. covering the resources, expertise and operation of the radiation protection organisation, dosimetry, radiation measurements in the plant, radioactivity measurements of emissions, and monitoring of radiation in the environment. STUK required Fortum to develop its operations further at the Loviisa NPP and, among other things, intensify the radiation protection training of work planners and improve temperature conditions in rooms containing emission-measuring instruments, in line with the Operational Limits and Conditions. STUK required subsequently also TVO to develop further the radiation protection training and practising for maintenance operations at the Olkiluoto NPP.

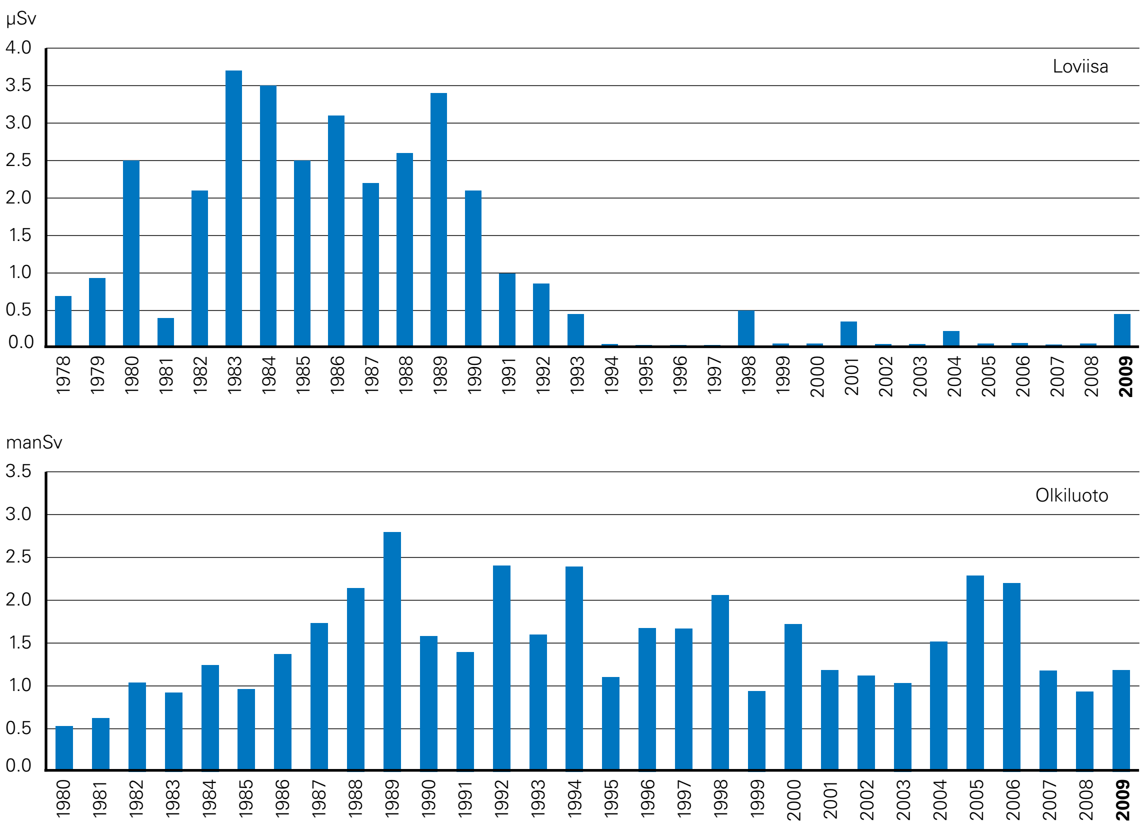


Figure 17. Calculated annual radiation exposures to the members of critical groups in the environment of the Finnish nuclear power plants. Doses have been clearly under the limit 100 µSv.

STUK carries out outage radiation protection inspections on-site during annual maintenances. The inspections at the Loviisa plant have shown e.g. that the radiation protection staff has developed job-specific introductory training, where certain employee categories are given special radiation protection training related to their duties. Contamination control of work areas at the plant during outages needs continuous attention and radiation protection control measures. STUK has carried out similar radiation protection inspections at the Olkiluoto NPP. The plant has developed the contamination measurements at the exits of the controlled area. However, it will be necessary in the future to assess whether the current level of permanent staffing is sufficient and verify the efficiency of certain outsourced radiation protection activities in the reactor refuelling area.

In conclusion, Finnish regulations and practices are in compliance with Article 15.

Article 16. Emergency preparedness

1. ***Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.***
2. ***Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.***
3. ***Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.***

Emergency preparedness on-site of NPPs

Regulations concerning emergency response arrangements at the NPPs are given in the Nuclear Energy Act, the Nuclear Energy Decree and the Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008). Detailed requirements and the monitoring procedures of STUK are given in the Guide YVL 7.4.

Fortum and TVO have analysed accident and safety-impairing events at the Loviisa and Olkiluoto NPPs, and these are specified in the safety analysis reports of the plants. These analyses have been used as the basis for planning the Finnish nuclear power plant emergency response arrangements.

Emergencies are classified and described briefly in the plant's emergency plan. The notifications and alarms to plant personnel and authorities required by different classes of emergencies, as well as the scope of operations of the emergency response organisation pertaining to the type of emergency, are described in the emergency procedures.

A person responsible for emergency response arrangements have been appointed both for the Loviisa and Olkiluoto nuclear power plants. The emergency response organisation has been described in the emergency plan and procedures, updated with regard to personnel changes once a year. The more limited staffing of the emergency response organisation required for emergency standby state (alert) is defined in the shift supervisor guides for the emergency response.

The facilities of the emergency response organisation at the Loviisa and Olkiluoto nuclear power plants include system for a major display of plant process and radiation data in the process computer. Most important data is transmitted also to the STUK's emergency response centre.

Emergency response training and exercises are annually arranged for the emergency response organisation of the nuclear power plants. The emergency response training has included classroom and action group-specific practical training as well as special training, such as first aid, fire and radiation protection training. In addition to severe accidents, the emergencies covered by the emergency response exercises also included conditions classified as emergency standby. The content and scope of the training as well as feedback obtained from the training are assessed in the inspections of the STUK's periodic inspection programme.

STUK verifies the preparedness of the organisations operating nuclear power plants in yearly on-site inspections. Emergency preparedness at the Loviisa and Olkiluoto power plants meet the key regulatory requirements. At the Loviisa NPP, the inspection has focused on the reorganisation of the emergency response organisation, testing of the connections used for plant data transfer during an emergency situation and the securing of connections, and the development of the power plant's alerting and training procedures. The renewed emergency premises at the Loviisa NPP could be now better utilised in real situation, because equipment and accessories in the premises are upgraded. The emergency exercise of the Loviisa power plant was arranged in the rebuilt emergency response centre premises early 2010. It was also an emergency and rescue operation exercise under the leadership of the State Provincial office of Southern Finland.

The inspections at the Olkiluoto NPP have covered, among other things, the tasks of the action groups of the plant's emergency response organisation and the procedures and training for the nearby construction sites of Olkiluoto 3 reactor and Onkalo rock examination facility related to the spent fuel disposal facility concerning the evacuation of personnel from the site in case of an accident at Olkiluoto units 1 or 2. The licensee and the authorities have engaged in close co-operation. Personnel mustering exercises have been organised in the limited area of the Olkiluoto 3 construction site.

Wind measuring sensors of the weather mast at the Olkiluoto plant site have been replaced to new acoustic type sensors. The new sensors are more versatile and accurate. More comprehensive data is now available on the weather conditions, including the dispersion calculation methodology. STUK required that the Loviisa and Olkiluoto plants assess not only the development of the single weather mast system but also that of the off-site additional measurements and the related predictive models with regard to the dispersion of any releases into the atmosphere. Topical reports from the plants and utilities will be issued in 2011.

New, more accurate and stable real-time radiation monitoring instruments have been installed into the external radiation monitoring network of the Olkiluoto NPP surroundings. The installed instrumentation is now identical to that in the nationwide radiation monitoring network of Finland for emergency purposes. Both the Loviisa and Olkiluoto monitoring networks have up to 15 radiation measurement stations, five and four of them close to the plant area and the others in a half circle at 5 km distance from the plant. Three additional measurement stations will be installed in the vicinity of Olkiluoto 3 before the plant unit is in operation.

Training events on preparation for an accident at the Olkiluoto nuclear power plant were organised for the fire and rescue authorities throughout the area of the Satakunta regional rescue services and the personnel of the Provincial State Office of Western Finland. In 2008, an emergency and rescue operation exercise was carried out at the Olkiluoto power plant under the leadership of the State Provincial Office of Western Finland.

Off-site arrangements

In addition to the on-site emergency plans established by the licensees, off-site emergency plans required by the rescue legislation (468/2003) are prepared by regional authorities. The requirements for off-site plans and activities in a radiation emergency are provided in the Decree of the Ministry of Interior (774/2001). STUK is an expert body to support the Ministry of Interior in the emergency response in the case of nuclear and radiological accidents. STUK publishes VAL Guides for emergency response. Guide VAL 1 (2010) "Protective Actions in Nuclear or Radiological Emergency" provides detailed guidance. In the case of an accident the local authorities are alerted by the operating organisation of the plant.

STUK has an Emergency Preparedness Manual for its own activities in the case of a nuclear accident or radiological emergency. STUK has an expert on duty for 24 hours a day. The message on an exceptional event (alarm) can be received from the operating organisations of the facilities, or automatically from the radiation monitoring network that is dense in the whole country (300 measuring stations), or from foreign authorities.

The off-site plans include provisions to inform the population in the case of an accident. Written instructions on radiation emergencies, emergency planning and response arrangements have been provided to the population living within the 20 km Emergency Planning Zone. These are regularly updated and distributed.

The regulations and guides are tested in off-site emergency exercises conducted every third year. Full scale off-site emergency and rescue exercise was carried out in Finland in 2008 based on the Olkiluoto nuclear power plant accident scenario. In 2010 the national exercise concerned the Loviisa nuclear power plant.

The rescue planning is strengthened in a co-operation between the nuclear power plant, regional rescue centre and STUK. This includes common training and regular meetings.

Information to the neighbouring countries

Finland is a party to the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, done in Vienna in 1986. Being a member of the European Union, the Council Decision (87/600/EURATOM) on Community arrangements for the early exchange of information in the event of a radiological emergency applies in Finland, too. In addition, Finland has respective bilateral agreements with Denmark, Germany, Norway, Russia, Sweden and Ukraine. Accordingly, arrangements have been agreed to directly inform the competent authorities of these countries in the case of an accident.

In addition to the domestic nuclear emergency exercises held annually on each nuclear power plant site, STUK has taken part in international emergency exercises. STUK has also participated as a co-player in emergency exercises arranged by the Swedish and Russian nuclear power plants and authorities. Neighbouring countries have been actively invited to take part in the Finnish exercises.

In conclusion, Finnish regulations and practices are in compliance with Article 16.

Article 17. Siting

Each Contracting Party shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

i. ***for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;***

ii. ***for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;***

iii. ***for re-evaluating as necessary all relevant factors referred to in sub-paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installation; for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.***

Regulatory approach to siting

Requirements for the siting of a nuclear power plant are provided in the Nuclear Energy Act and the Nuclear Energy Decree. The application for a Decision-in-Principle has to include e.g.:

- a description of settlement and other activities and town planning arrangements at the site and its vicinity
- an description of the suitability of the planned location for its purpose, taking account of the impact of local conditions on safety, security and emergency response arrangements, and the impacts of the nuclear facility on its immediate surroundings
- an assessment report in accordance with the Act on the Environmental Impact Assessment Procedure (468/1994) as well as a description of the design criteria the applicant will observe in order to avoid environmental damage and to restrict the burden to the environment.

More detailed requirements on the Environmental Impact Assessment (EIA) are provided in the Decree on Environmental Impact Assessment Procedure (713/2006).

In the design of a nuclear power plant, site-related external events have to be taken into account. Government Decree 733/2008 provides as follows: “The safety impact of local conditions, as well as the security and emergency preparedness arrangements, shall be considered when selecting the site of a nuclear power plant. The site shall be such that the impediments and threats posed by the facility to its environment remain extremely minor and heat removal from the plant to the environment can be reliably implemented.” STUK issued in 2001 the Guide YVL 1.10 “Safety criteria for siting a nuclear power plant”, which describes generally all requirements concerning the site and surroundings of a nuclear power plant, gives requirements on safety factors affecting site selection and covers regulatory control. Requirements on seismic design are set forth in the Guide YVL 2.6. Deterministic analyses are made to assess the impact of various natural phenomena and other external events. The probabilistic risk assessment required for the safety review of Construction and Operating Licence applications provides information on risks caused by external events.

The general principle in the siting of nuclear power plants is to have facilities in a sparsely populated area and remote from large population centres. In the vicinity of the plant, no activities are allowed that could pose an external threat to the plant. Site characterisation is performed based on geological, seismic, hydrological and meteorological factors as well as on transport routes and risks, industrial activities, agriculture, nature and population. Extreme meteorological conditions and consequences (e.g. frazil ice formation) have to be taken into consideration in the site evaluation and plant design.

In connection with the decisions for construction of the Loviisa and Olkiluoto plants in the 1970s, site-related safety requirements were quite easily and practically achievable in a sparsely populated country like Finland. The precautionary action zones have only a few tens of permanent inhabitants. Similar attention was not given to the recreational houses and the transient summertime population in the coastal area (mainland and islands) where the conditions might be demanding for efficient emergency preparedness and rescue action. The number of recreational houses on the seaside within 5 km the existing plants is of the order of 400–500.

Finland is a party to the Convention on Environmental Impact Assessment in a Transboundary Context, done in Espoo in 1991. The Convention is applied for Finnish nuclear facility projects by providing a full participation to all neighbouring countries which announce the willingness to participate in the environmental impact assessment procedure in question. In Finland, the EIA is conducted at an early stage of a NPP project, prior to the selection of the plant design, based on the power range of the plant and on general information on the available designs.

The bilateral agreements mentioned under Article 16 include provisions to exchange information on the design and operation of nuclear facilities. In the European Union a specific statement is also prepared for each new nuclear power plant unit in a member state before authorisation of the operation (Euratom Treaty, Article 37). This is based on a General Data report submitted by the member state and on its examination in a plenary meeting of Group of Experts. For Olkiluoto unit 3 this process was conducted in 2010. Based on the legislation on land use planning, statements from neighbouring countries must be requested for the land use plans of a nuclear power plant. In practice the regional plan drafts for Fennovoima’s two northern sites were submitted to all Baltic Sea countries and Norway (8 altogether).

Re-evaluation of site related factors

The operating licence for a nuclear facility is granted for a fixed term. For the licence renewal of the Loviisa units in 2005–2007 and the Periodic Safety Review of the Olkiluoto units in 2007–2009, comprehensive re-assessments of safety, including the environmental safety of the nuclear facility and the effects of external events on the safety of the facility, were conducted by the licensees and reviewed by STUK. The assessments covered meteorology, hydrology, geology, seismology, population and use of land and sea area. During the operation of a nuclear facility, the Final Safety Analysis Report (FSAR), including its site-specific parts, has to be periodically reviewed and updated as needed. A detailed re-evaluation of the site related factors was carried out in 2007–2009 for the Olkiluoto and Loviisa sites in connection with the Environmental Impact Assessment and Decision-in-Principle procedures for new NPP units.

Assessment of new nuclear power plants and candidate sites

The Construction Licence for the Olkiluoto 3 unit was granted by the Government in February 2005. The construction is in progress. Site-related factors were evaluated and reviewed in connection with the Construction Licence procedure. Further clarifications have been submitted by the licensee during construction.

In 2007, initiatives for building additional nuclear power reactors in Finland were announced. Environmental Impact Assessment (EIA) procedures were carried out for the possible Olkiluoto 4 and Loviisa 3 units in 2007–2009.

A new nuclear power company, Fennovoima, was founded in 2007. The company started a preliminary site survey process, mainly on the coast of the Gulf of Bothnia (the northern gulf of the Baltic Sea) and on the eastern Gulf of Finland (the eastern gulf of the Baltic Sea), the northernmost candidate site being 20–30 km from the borderline of Sweden. Fennovoima prepared an EIA programme and subsequently an EIA report for three (originally four) alternative new candidate sites in 2007–2009.

The EIA procedure did not reveal any major nuclear or radiation safety issues as regards the proposed new NPP sites or new units on the existing sites. EIA was anyhow a tool to cope comprehensively with the environmental issues depending on the specific site (e.g. sea environment and eutrophication, special natural species and phenomena, biodiversity, Natura natural reserve assessment, fisheries, salmon migration, combined heat and power production) and to increase the opportunity for citizens and authorities to receive information, become involved in the planning and express their opinions on the project.

Comments were requested from altogether nine countries near the Baltic See by the Finnish Environmental Ministry. Several comments from e.g. Estonia, Sweden and Germany were given and considered by the Finnish authorities. Additionally, the Austrian Government as a party of the Espoo convention sent their statement on each EIA and requested for consultation in Finland. Thus, subsequent meetings were arranged in 2008–2009 at the Finnish Ministry of the Environment where a Finnish delegation of experts from the utility concerned, STUK and the Ministry of Employment and the Economy gave detailed explanations to the questions provided.

Separate applications for the Government's Decision-in-Principle for new NPP units were submitted in 2008 and 2009 by TVO, Fortum and Fennovoima. The relevant site-related factors potentially affecting the safety of a the planned new NPP units and the related nuclear facilities during their projected lifetime were again evaluated for the existing Loviisa and Olkiluoto sites and for the alternative new sites at Pyhäjoki, Simo and Ruotsinpyhtää proposed by Fennovoima. In late 2009, Fennovoima removed the Ruotsinpyhtää site from its application for a Decision-in-Principle. The evaluations were reviewed by STUK and other expert organisations in their respective fields. In addition to the Finnish regulations, IAEA Safety Requirements and Safety Guides and WENRA requirements were considered in the review.

Specific issues regarding the new sites are the size of precautionary action zone (5–6 km radius in Finland), the limitation of maximum population within it which may be affected in a severe accident situation and the possibility to evacuate the population. According to the Finnish regulations, an early evacuation before an expected release shall be possible within a time of four hours from the evacuation decision. The population in 2010 in the vicinity of the Finnish candidate sites is internationally compared relatively small (maximum of 3000 inhabitants up to 6 km from the site at Simo). Three other issues which have to be taken into account, if the northernmost Simo site is chosen, are seismic conditions (similar to typical Central European sites), pack ice and the possible need of restrictions on the approach area of the Kemi-Tornio airport.

According to STUK's preliminary safety assessments, no site related factors were found at any of the sites which would prevent building the proposed new NPP units and the related other nuclear facilities according to the safety requirements. More detailed evaluation of the site related factors will be conducted in connection with the Construction Licence application.

In conclusion, Finnish regulations and practices are in compliance with Article 17.

Article 18. Design and construction

Each Contracting Party shall take the appropriate steps to ensure that:

- *i.* ***the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;***
- *ii.* ***the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;***
- *iii.* ***the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.***

Implementation of defence in depth

Regulatory requirements regarding nuclear power plant design and construction

According to the Government Decree 733/2008, several levels of protection have to be provided in the design of a nuclear power plant. The design of the nuclear facility and the technology used is assessed by STUK when reviewing the applications for a Decision-in-Principle, Construction Licence and Operating Licence. Design is reassessed against the advancement of science and technology, when the Operating Licence is renewed and in the periodic safety reviews.

In the design, construction and operation, proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents and mitigate their consequences. A nuclear power plant shall encompass systems by means of which operational transients and accidents can be quickly and reliably detected and the aggravation of any event prevented. Effective technical and administrative measures shall be taken for the mitigation of the consequences of an accident. The design of a nuclear power plant shall be such that accidents leading to extensive releases of radioactive materials must be highly unlikely.

Dispersion of radioactive materials from the fuel of the nuclear reactor to the environment shall be prevented by means of successive barriers which are the fuel and its cladding, the cooling circuit of the nuclear reactor and the containment building. Provisions for ensuring the integrity of the fuel, primary circuit and containment are included.

In ensuring safety functions, inherent safety features attainable by design shall be made use of in the first place. If inherent safety features cannot be made use of, priority shall be given to systems and components which do not require an external power supply or which, in consequence of a loss of power supply, will settle in a state preferable from the safety point of view (passive and fail-safe functions).

In order to prevent accidents and mitigate the consequences thereof, a nuclear power plant shall be provided with systems for shutting down the reactor and maintaining it in a subcritical state, for removing decay heat generated in the reactor, and for retaining radioactive materials within the plant. Principles ensuring the implementation of these safety functions even in the event of a malfunction must be applied in designing the systems in question. Such principles are redundancy, separation and diversity. The most important systems necessary for transferring the plant to, and remaining in, a controlled state must be capable of fulfilling their function even if any individual system component is inoperable and even if any other component of the same system or of a supporting or auxiliary system necessary for its operation is simultaneously out of use due to required repair or maintenance. Common-cause failures in safety systems shall only have minor impacts on plant safety. Furthermore, a nuclear power plant shall have on-site and off-site electrical power supply systems. The execution of safety functions shall be possible by using either of the two electrical power supply systems.

The plant shall also be provided with systems, structures and components for controlling and monitoring severe accidents. These shall be independent of the systems designed for operational conditions and postulated accidents. Systems necessary for ensuring the integrity of the containment building in a severe accident shall be capable of performing their safety functions, even in the case of a single failure.

Special attention shall be paid to the avoidance, detection and correction of any human error during design, construction, operation and maintenance. The possibility of human error shall be taken into account in the design of the nuclear power plant and in the planning of its operation and maintenance, so that human errors and deviations from normal plant operations due to human error do not endanger plant safety. The impacts of human error shall be reduced by using various safety design methods, including defence-in-depth, redundancy, diversity and separation.

Detailed requirements are given in Guides YVL 1.0, YVL 2.0, YVL 2.4, YVL 2.7, YVL 3.0, YVL 4.3, YVL 5.2, YVL 5.5, YVL 6.2.

An assessment of the design of the facility and related technologies is made by STUK for the first time when assessing the application for a Decision-in-Principle. Later on, the evaluation is continued when the Construction Licence application is reviewed. Finally, the detailed evaluation of systems and equipment is carried out through their design approval process. The design of Loviisa plant units was reassessed by STUK in 2005–2007 and Olkiluoto plant units in 2007–2009 in the periodic safety review process.

Application of defence in depth concept at the Finnish NPPs

During the time period 2007–2009, no significant faults or signs of wear were detected in the integrity of equipment and structures critical to plant safety. The condition of the multiple barriers containing releases of radioactive substances has remained good both at the Loviisa and Olkiluoto plants.

A fuel leak was observed at the Loviisa unit 2 on 28 November 2008. The leak was detected as the activity of exhaust gases increased. All fuel bundles were tested during 2009 annual outage and leaking fuel bundles were removed from the reactor. Leaking fuel rod was detected also at the Loviisa unit 1 on November 2009. The previous fuel leak in Loviisa before these two cases occurred in 1999.

During the 2009 annual outage a new type of fuel bundles were loaded into the reactor at the Loviisa NPP. The fuel enrichment is slightly higher which has an impact on shutdown margin of the reactor. Also six rods in the bundle contains burnable poison. Acceptable control rod positions in the Operational Limits and Conditions were also changed in order to keep the shutdown margin of the reactor core at the same level as before.

TVO aims to prevent fuel leaks by more effectively preventing loose parts from entering the reactor, but a small fuel leak caused by a loose part was detected at the Olkiluoto unit 2 during the 2006–2007 operating cycle. TVO submitted to STUK for approval the preinspection documentation of new type fuel bundles, scheduled for loading in the reactor in spring 2009. The number of fuel rods per bundle has been increased and the diameter of the rods has been correspondingly reduced. Partial length rods have been introduced in these bundles, and the bundle length has slightly increased. STUK approved the documentation in April 2009.

Inspections of the reactor pressure vessel and piping revealed no deterioration of the materials at the Finnish NPPs. The steel liner of the Loviisa NPP containment is subjected to a leak tightness test at four-year intervals. The reactor containment at the Olkiluoto NPP is subjected to a leak tightness test three times during a 12-year period. In addition, leak tightness tests have been made systematically to containment isolation valves, personnel airlocks and containment penetrations. The results show that the leak tightness of the containment building has remained acceptable at the both NPPs. At the Olkiluoto NPP, strain measurements of structures and a survey of fractures in the containment indicate that no changes have taken place in the structures. During the leak tightness tests performed at the Olkiluoto unit 1 in 2008 and at the Olkiluoto unit 2 in 2010, strain did not exceed the elastic zone, and new fractures were not created. The structures are in good condition at the Olkiluoto NPP.

During the time period 2007–2009, no significant failures were observed in the Loviisa plant's safety functions and the systems, equipment and structures implementing them. At the Olkiluoto NPP, the overvoltage event challenged the safety functions in 2008. A high voltage peak caused by an operational transient in the voltage regulator of the main generator caused an uncontrolled coastdown of the core coolant flow. The event did not cause a hazard to the environment, but it revealed a significant flaw in the overvoltage protection of the electrical systems at the plant. At the Olkiluoto units 1 and 2, the uncontrolled trips of reactor coolant pumps caused by overvoltage are temporarily prevented by modifying the protective relay functions in the auxiliary power supply network. In addition, the power company amended the plant operating instructions. The event is described in more detail in Annex 2.

A potential undervoltage event identified at the Oskarshamn power plant was taken into account in the safety improvement programme at the both Finnish NPPs. Fortum was requested to carry out an analysis of the impact of long term undervoltage periods in the grid on the Loviisa power plant's equipment. At the Olkiluoto NPP, analysis concentrated in particular on the effects of voltage drops of long duration on the pump motors in safety systems. These analyses were completed during 2009. Similar analyses have been prepared before, and these new ones were intended to study the current situation of plants.

In connection with the Loviisa plant's licence renewal, Fortum has also prepared a plan on actions aimed at further enhancing the safety of the plant units in the future, necessitating a revision of the analyses. The most important ongoing plant modification project related to the Defence in Depth concept at the Loviisa plant is the upgrade of the I&C systems of the plant units. The project started in 2004 with the construction of a new I&C building, and the project is to be completed in 2014.

Fortum and TVO have also reviewed all of the analyses of transient and accident situations at the Loviisa and Olkiluoto nuclear power plants in connection with the operating licence renewal and periodic safety review. Deterministic safety assessment is described in more detail under Article 14.

Severe accidents were not taken into account in the original design of the operating Finnish nuclear power plants. However, since the commissioning of the plants, many improvements have been implemented to mitigate the consequences of severe accidents. Mitigations systems are described in detail in Annex 2.

For the Olkiluoto unit 3, application of the Defence in Depth principle was presented in the Preliminary Safety Analysis Report (PSAR). The design follows the principles laid down in the Government Decree 733/2008. Compared with the existing reactors, the possibilities to mitigate the consequences of the severe accidents are taken into account already in the early design phase. This is achieved by implementing features to ensure containment integrity. Design provisions include e.g. core catcher for corium spreading and cooling, hydrogen recombination, and containment heat removal. In addition, aircraft crash protection design requirements for both a military aircraft and a large passenger aircraft are taken into account.

Incorporation of proven technologies

It is stated in the Government Decree 733/2008 that proven or otherwise carefully examined high-quality technology shall be employed in the design, construction and operation of a nuclear power plant. The respective detailed requirements are provided in many YVL Guides.

Practical implementation of the new safety requirements and procedures to ensure adequate reliability of digital instrumentation and control systems in the modernisation projects of the operating power plants and in the design of the new nuclear power plant can be considered as one of the major challenges for the next ten years. This includes also the issues related to the digital control rooms.

At the Loviisa plant, the I&C systems are currently being renewed. The project began in 2002 with basic conceptual design; implementation begun in 2004 with construction of new buildings to accommodate the new systems. The project is intended to be completed in 2014. The renewal is proceeding in carefully designed phases such that the I&C systems are renewed step by step, allowing each renewed system to be taken into operation during normal refuelling outages. The first phase was implemented at the Loviisa unit 1 during the 2007 annual maintenance, including the upgrade of the I&C of reactor power limitation and control rod control. Control room facilities are also renewed in phases with the system renewal. For example, large screen display devices were installed in the control rooms in 2006 and 2007.

STUK has reviewed the licensing documents related to the project, such as Conceptual Design (including Defence-in-Depth and Diversity assessment), System pre-inspection documents for various systems, and also Preliminary Suitability documents pertaining to the qualification of the digital I&C platforms being used in the project. STUK has also witnessed the installations in connection with the oversight of annual maintenance.

At the Olkiluoto nuclear power plant units 1 and 2, changes in the control room are made gradually. Digital instrumentation and control technology has already been implemented in the modernised systems. The safety systems man-machine-interface is still of conventional technology. The development of detailed safety requirements and procedures to ensure adequate reliability of such systems is still underway.

Design for reliable, stable and manageable operation

Government Decree 733/2008 requires that a nuclear power plant's control room shall contain equipment which provide information about the plant's operational state and any deviations from normal operation as well as systems which monitor the state of the plant's safety systems during operation and their functioning during operational transients and accidents. Furthermore, it requires that a nuclear power plant shall contain automatic systems that maintain the plant in a safe state during transients and accidents long enough to provide the operators a sufficient time to consider and implement the correct actions. Special attention shall be paid to the avoidance, detection and repair of human errors. The possibility of human errors shall be taken into account both in the design of the nuclear power plant and in the planning of its operation so that the plant withstands well errors and deviations from planned operational actions.

Plant systems reliability and human factors are systematically considered in the probabilistic safety analyses. The analyses support the efforts to eliminate accidents or to mitigate their consequences. The probabilistic safety analyses are subject to the approval of STUK. Human factors in relation to the monitoring and control of Finnish nuclear power plants area described under Article 12. Significant effort has been devoted by the regulator and utilities involved in the assessment of modern control room concepts. Existing plants are moving towards so-called hybrid control rooms, where normal operation is based on digital controls and video screens, but safety backups are still implemented also using traditional mosaic displays, analogy indicators and switches.

In conclusion, Finnish regulations and practices are in compliance with Article 18.

Article 19. Operation

Each Contracting Party shall take the appropriate steps to ensure that:

- *i.* ***the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning programme demonstrating that the installation, as constructed, is consistent with design and safety requirements;***
- *ii.* ***operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;***
- *iii.* ***operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;***
- *iv.* ***procedures are established for responding to anticipated operational occurrences and to accidents;***
- *v.* ***necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;***
- *vi.* ***incidents significant to safety are reported in a timely manner by the holder of the relevant licence to the regulatory body;***
- *vii.* ***programmes to collect and analyse operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;***
- *viii.* ***the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning and disposal.***

Initial authorisation

According to Government Decree 733/2008 Section 22, in connection with the commissioning of a nuclear power plant, the licensee shall ensure that the systems, structures and components and the plant as a whole operate as designed. At the commissioning stage, the licensee shall ensure that an expedient organisation is in place for the future operation, alongside a sufficient number of qualified personnel and instructions suitable for the purpose.

Requirements for the commissioning programme are set forth in the Guide YVL 2.5. According to the Guide YVL 2.5, the purpose of the commissioning programme is to give evidence that the plant has been constructed and will function according to the design requirements. Through the programme possible deficiencies in design and construction can also be observed. The Operating Licence is needed before fuel loading into the reactor. Authorisation for fuel loading is given by STUK after its specific inspection where readiness of the power plant and operating organisation is checked. Furthermore, according to the Nuclear Energy Decree, the various steps of the commissioning, i.e., criticality, low power operation and power ascension, are subject to the approval of STUK.

The commissioning programme is described in the Preliminary and Final Safety Analysis Reports. The participation of the operating staff in the commissioning programme is a requirement of the Guide YVL 1.6. The commissioning programme is to be submitted to STUK for approval. The detailed commissioning test programmes and test reports for systems in safety classes 1, 2 and 3 are submitted separately to STUK for approval. STUK witnesses commissioning tests and assesses the test results before giving stepwise permits to proceed in the commissioning.

Olkiluoto unit 3 commissioning

Preparations for commissioning of the Olkiluoto unit 3 are underway. Commissioning is divided into 5 phases, starting with component commissioning. This is followed by system commissioning and plant level commissioning in cold and hot conditions. Fuel loading requires Operating Licence and STUK's approval. First criticality and power test can then follow. Latest phase is demonstration run. All commissioning documentation is part of Commissioning Manual which includes also organisational procedures. Vendor has prepared an Overall Commissioning Programme as well as system level commissioning documentation and TVO and STUK have already approved some of these. Preparations for plant level commissioning are still underway. STUK oversees the commissioning of safety classified systems and related result documentation is provided for STUK's review.

Before TVO can start commissioning activities, all systems go through commissioning inspection. This step certifies that components and system are properly installed and they function as designed. This is also part of pressure vessel requirements. As part of the construction inspection programme inspections, STUK oversees TVO's actions for ensuring that the plant is commissioned appropriately.

Trial tests in the Loviisa NPP for power uprate in the 1990's

Fortum planned and carried out a trial test programme after the modernisation and power uprate project in 1994–1997. Normal operation and in a limited way also transient behaviour of the plant were studied in the trial tests. Studies were made by means of the plant simulator and the results of transient analyses were used in the planning of the trial test programme. Due to the small number of plant modifications required for the power increase of the Loviisa plant, a simple trial test programme supported by the simulator studies was considered as appropriate and acceptable. According to the trial test programme, transient tests and extensive measurements concerning the state of the plant were carried out at various power levels. Based on the trial tests it was considered that the units operate as planned also at the increased power level. The increase of the power level was licensed in 1998.

Trial tests in the Olkiluoto NPP for power uprate in the 1990's

Test operations were conducted in stages at different power levels under STUK's supervision and within the frames permitted by STUK. Before uprating the reactor power to a higher power level STUK conducted a safety review concerning the test operation for the power level in question and asked the Nuclear Safety Advisory Committee for a statement concerning the review before granting the test operating licence.

Test operation programmes that included the entire plant units and were drawn up by TVO, were based on the original commissioning programmes that were run through during the start-up phase and that were modified taking into account the test requirements caused by the modernised systems. For the long-term test operation of the plant units the thermal power of reactor units were uprated step by step from the nominal power of 2160 MW to 2500 MW.

The most significant plant transient tests of the test operation were the load rejection test, turbine trip test and the by-pass test of the high-pressure preheaters. STUK considered it necessary to continue the test operation at the 2500 MW power level for about two months before issuing a statement in favour of continuing the operation of the plant units at the 2500 MW power level. The increase of the power level was licensed in 1998.

Operational Limits and Conditions

Nuclear Energy Decree requires that the applicant for an Operating Licence must provide STUK with the Operational Limits and Conditions (OLCs). The OLCs shall at least define limits for the process parameters that affect the safety of the facility in various operating states, provide regulations on operating restrictions that result from component failures, and set forth requirements for the testing of components important to safety. Technical and administrative requirements and restrictions for ensuring the safe operation of a nuclear power plant shall be set forth in the plant's OLCs. Guide YVL 1.1 requires that the minimum staff availability in all operational states and the limits for the releases of radioactive substances are also defined in the document.

The OLCs have been established for each nuclear power plant unit and are updated based on operational experiences, tests, analyses and plant modifications. The OLCs are subject to the approval of STUK prior to the commissioning of a facility. Strict observance of the OLCs is verified by STUK's continuous oversight, reporting requirements and through a periodic inspection programme. The OLCs, operating procedures and other plant documentation need to be updated as part of plant modification process.

Fortum has established the OLCs for the Loviisa units 1 and 2, and STUK has reviewed and accepted them. The OLCs are continuously updated, and all the changes need to be approved by STUK. The limitations and conditions of the reactor and plant operation, the requirements for periodic tests and the essential administrative instructions are presented in the OLCs.

The OLCs for Olkiluoto units 1 and 2 determine the limits of process parameters that affect the plant safety, for different operating modes, set the provisions for operating limits caused by component inoperability and set forth the requirements for the tests that are conducted regularly for components important to safety. Furthermore, the OLCs include the bases for the set provisions.

Figure 18 presents the number of exemptions and deviations from the Operational Limits and Conditions. The main reason for the large number of exemptions at the Loviisa NPP in years 2002–2003 was the project to renew the radiation monitors that required exemptions in all operational states. During the period 2007–2009, most of exemption applications concerned I&C renewal or overdue repairs of component failures.

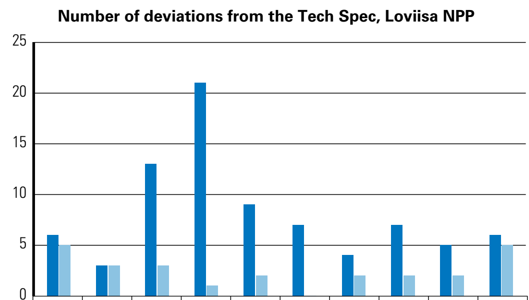
In the case of the Olkiluoto NPP, the main reason for the exemptions has been the conduct of maintenance and repair works. Deviation from the OLCs has to be analysed and reported by the licensee (causes, safety assessment and corrective actions). Olkiluoto NPP deviations reported in 2007–2009 concerned mainly the delays in the periodic tests.

Procedures for operation, maintenance, inspection and testing

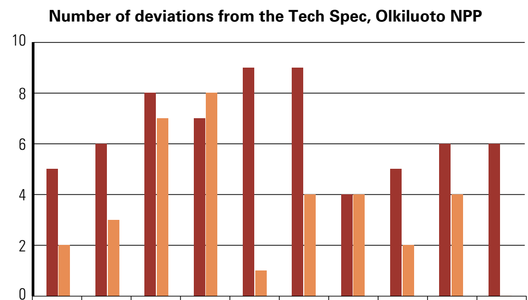
Government Decree 733/2008 Section 23 requires that the control and supervision of a nuclear power plant shall utilise written instructions that correspond to the current structure and state of the plant. Written orders and related instructions shall be provided for the maintenance and repair of components. Section 26 requires that the plant shall have a condition monitoring and maintenance programme for ensuring the integrity and reliable operation of systems, structures and components. More detailed requirements are presented in the Guides YVL 1.1, YVL 1.8 and YVL 1.9. The procedures for operation, maintenance, inspection and testing have been established at both Finnish nuclear power plants. The procedures shall be approved by the licensee itself, and most of them are required to be submitted to STUK for information. STUK verifies by means of inspections and continuous oversight performed by resident inspectors that approved procedures are followed in the operation of the facility.

Loviisa NPP

A structured system of procedures exists at the Loviisa plant. The procedures cover work processes and functions important to safety and availability. The system of procedures is a part of the quality system of the plant. Strict requirements have been set in the Quality Assurance Manual for the coverage, responsibilities, updating and observance of the procedures. According to the Manual the evaluation of the system of procedures is included in the annual review of the coverage and effectiveness of the quality assurance programme. The state of the



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Exemptions	6	3	13	21	9	7	4	7	5	6
Deviations	5	3	3	1	2	0	2	2	2	5



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Exemptions	5	6	8	7	9	9	4	5	6	6
Deviations	2	3	7	8	1	4	4	2	4	0

Figure 18. Number of exemptions and deviations from the Operational Limits and Conditions in the Loviisa and Olkiluoto NPPs.

plant procedures is acceptable at the Loviisa plant. Procedures are maintained, evaluated and developed systematically and in a controlled way. The most important procedure types are:

- Administrative procedures including Organisational Manual and Administrative Rules,
- Operating procedures and testing procedures,
- Procedures for emergency and transient situations,
- Fuel handling procedures,
- Radiation protection procedures, and
- Maintenance procedures.

Loviisa plant has upgraded computer systems used in managing documentation and permit-to-work system. By means of a work order system it is ensured that the plant operators are aware of the state and configuration of the unit. Fortum has developed, and develops further, its work order system based on accumulated operating experiences. In addition to the work order system the operators in the main control room of the units follow failures, repairs and preventive maintenance of the components referred to in the Operating Limits and Conditions. A shift supervisor gives a permit to start a specific work when he has evaluated the work plans specified in the work order system, taking into account the operability requirements of the systems and components set in the Operational Limits and Conditions.

The maintenance activities of the Loviisa units 1 and 2 cover preventive, predictive and repairing maintenance as well as implementation of modification works, spare part maintenance and activities during outages. The scheduling of the modification planning for the next maintenance outage is fixed in order to get enough time for preparations. Minor modifications are concentrated to every second annual maintenance outage and major works are carried out every fourth year. This is accomplished by starting from a long term investment planning which converts into a long term modification plan.

The functioning of the systems and components is ensured with regular tests. The systems and components to be tested and the time periods of the tests are presented in the Operational Limits and Conditions. At least the respective periodic tests are required after the modification and repairing works and maintenance activities requiring dismounting. The performance test programme to be carried out after an essential modification is required to be approved by STUK in advance. In addition, inspections regarding to the functioning and condition of components are carried out when necessary based on operating experiences from other plants and on the advancement of technical knowledge. Other operating organisations of VVER-type reactors have been essential sources of operating experiences in this respect.

STUK oversees monitoring and maintenance activities as well as repair and modification works with regular inspections and continuous oversight performed by resident inspectors. During inspections it is aimed to make sure that the utility has adequate resources, such as a competent staff, instructions, a spare part and material storage as well as tools for the sufficiently effective implementation of the monitoring and maintenance activities. Special subjects are the condition monitoring programmes for the carbon steel piping and their results. Special attention has also been paid to the reliable activities of subcontractors as well as to the technical competence of external human resources. Both the utility and STUK oversee companies that perform inspection activities and the technical competence of organisations that carry out various duties.

Olkiluoto NPP

The measures that are followed in the operation and maintenance of the Olkiluoto units 1 and 2 are based on written procedures. The administrative and technical procedures needed in the operation of the Olkiluoto units 1 and 2 have been gathered into the Operating Manual. The Operating Manual contains also necessary transient and emergency procedures for unusual conditions. The most important procedures have been reviewed by STUK. Updating and comprehensiveness of the procedures are among the inspection issues included in the STUK's periodical inspection programme. TVO updates the procedures when necessary and checks systematically that the procedures are up-to-date in four-year-intervals.

The administrative and technical procedures needed in the operation of the Olkiluoto units 1 and 2 have been gathered into the Operating Manual. The Operating Manual contains also necessary transient and emergency procedures for unusual conditions. The most important procedures have been reviewed by STUK. Updating and comprehensiveness of the procedures are among the inspection issues included in the STUK's periodical inspection programme. TVO checks the procedures periodically, approximately in four-year-intervals.

The Work Request System ensures that the operators of the plant are aware of the plant state. TVO has developed its Work Request System and will continue to do so, on the basis of operational experience. In the main control room of the plant units, the operators follow, in addition to the Work Request System, the failures, repairs and preventive maintenance of the components specified in the Operational Limits and Conditions. The Shift Supervisor grants the permission to begin a single work after inspecting the work plans and taking into account the operability requirements for the systems and components set forth in the Operational Limits and Conditions.

The maintenance activities of the Olkiluoto units 1 and 2 covers preventive and corrective maintenance as well as the design and execution of modifications, spare part service, outage actions and the related quality control. The Maintenance Department plans and implements the annual maintenance outages together with the Operation Department and Technical Support Department. Special attention has been paid to the reliable work of the subcontractors and to the technical competence of the external work force. The technical expertise of testing laboratories and contractors is controlled both by the power company and STUK.

The systems and the components that will be tested as well as the test dates are presented in the Operational Limits and Conditions. Periodical testing that correspond at least to the aforementioned, are required after maintenance measures that require modifications, repairing or disassembling. STUK's approval is required in advance for a functional test programme that is conducted after a significant modification. Inspections that concern the operability and condition of components are also conducted, if necessary, on the basis operational experience received from elsewhere and development of technical knowledge. The most significant sources of experience, in this sense, have been the Swedish BWR plants and international communication organs.

STUK oversees the condition monitoring and maintenance as well as the modification and repair work by regularly repeated inspections. The inspections aim to ensure that the power company has adequate resources such as a competent personnel, instructions, a spare part and material storage as well as the tools for adequately efficient implementation of condition monitoring and maintenance actions. Special items are the condition monitoring programmes of the carbon steel pipelines and their results.

Procedures for responding to operational occurrences and accidents

Government Decree 733/2008 Section 23 gives basic requirements for operating and emergency procedures.

At both Finnish nuclear power plants, procedures for anticipated operational occurrences and accidents are in use. To the extent found necessary, the procedures have been verified during operator training at the plant simulators. At both nuclear power plants there are also advanced safety panels for monitoring critical safety functions. STUK has independently evaluated the appropriateness and comprehensiveness of the procedures for anticipated operational occurrences and accidents.

Plant specific symptom based EOPs (Emergency Operating Procedures) have been available at the Olkiluoto units since late 1980's. TVO has an action plan for developing isolation procedures. STUK required in decision made in the last periodic safety review (PSR) that after this development work, TVO shall assess the need to develop other EOPs end submit a plan to STUK by the end of 2011.

The Loviisa specific EOP project was launched by Fortum in summer 2000. Before the project, an extensive feasibility study of different approaches was carried out. Most of the accident procedures are now in the new format, however, some scenarios are still controlled by the existing procedures. The project was finalised in early 2006. Next development of EOPs was started in 2007 to cover also the shutdown states during outages. The EOP development continues now as normal routine at the Loviisa plant. Fortum Technical Support is responsible for the strategies and the Loviisa plant for the validation, training and procedure layout.

Engineering and technical support

Government Decree 733/2008 Section 30 requires that the organisation shall have access to professional expertise and technical knowledge required for the safe operation of the plant, the maintenance of equipment important to safety, and the management of accidents. The requirements in the Guide YVL 1.7 also cover technical support. Competence of the engineering and technical support is supervised by the licensee. In addition, STUK carries out inspections and audits by which also the competence of the support staff is evaluated.

Teollisuuden Voima Oyj is an independent organisation and it has longstanding expertise in nuclear operations. TVO uses external expertise regularly in various design and modification activities when needed.

Fortum has under corporate structure own unit for technical support that provide support to the Loviisa NPP among other projects. There are also on-site experts at the Loviisa NPP for various engineering and technical support functions. In 2009, there were remarkable organisational changes in Fortum but these changes strengthened the role of the Technical Support from Loviisa NPP's point of view.

Reporting of incidents significant to safety

Guide YVL 1.5 provides in detail the reporting requirements on incidents. The Guide provides a number of examples of operational disturbances and events, which have to be reported to STUK. It also defines requirements for the contents of the reports and the administrative procedures for reporting, including time limits for submitting of various reports. STUK publishes information concerning significant events (INES ≥ 1) as press releases. Information from other events is published on STUK´s website. STUK describes the events also in its quarterly and yearly reports on nuclear safety that are also available to the general public through internet or paper reports in Finnish. STUK's Annual Report on nuclear safety (see Reference 1) summarises events from the whole year and is available to the general public through internet or paper reports both in Finnish and in English.

Figures 19 and 20 present the total number of reported events and INES classified (≥ 1) events at the Finnish nuclear power plants.

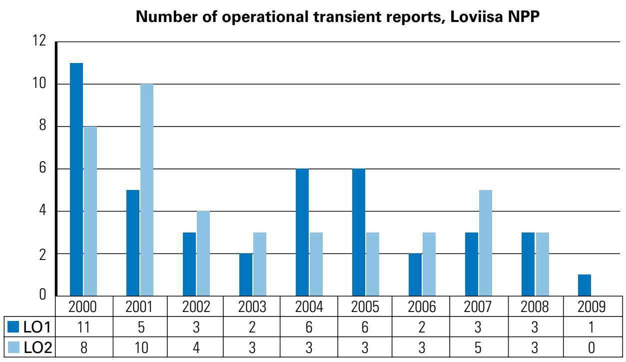


Figure 19. Annual total number of event reports (operational transient reports) submitted by Loviisa and Olkiluoto nuclear power plants.

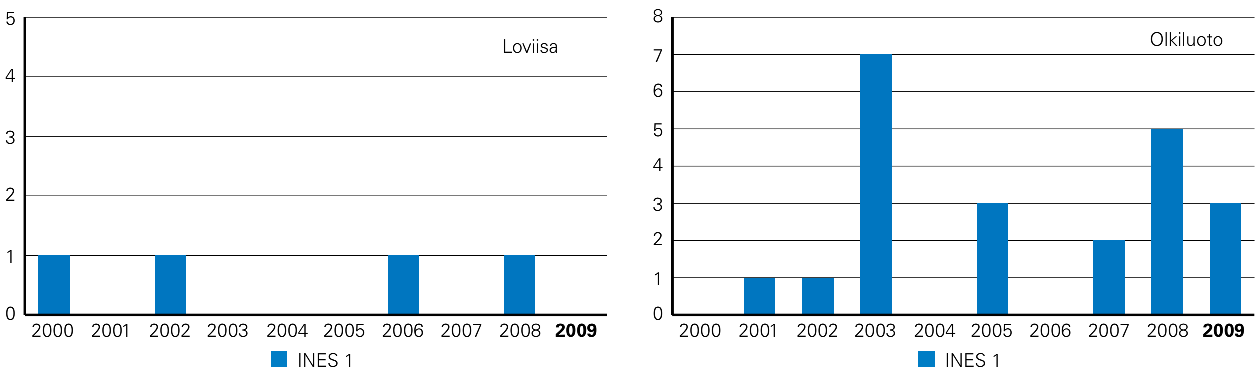


Figure 20. Annual total number of events at INES Level 1 and above at the Finnish nuclear power plants.

INES-classified events

At the Loviisa NPP, two events in 2007, three events in 2008 and six events in 2009 were classified on the International Nuclear Event Scale (INES). Only one in 2008 was classified as INES 1. The others were INES 0. The INES 1 event concerned an incorrect simulation in the reactor protection system. The simulation would have prevented a reactor trip resulting from the stopping of four reactor coolant pumps. The safety significance of the incorrect simulation was low, but deficiencies in the procedure made the event significant. The power company prepared a root cause analysis on the event. New procedures have been taken into use after the incident. Incident is described in more detail in Annex 2.

At the Olkiluoto NPP, seven events in 2007, eight events in 2008 and five events in 2009 were classified on the International Event Scale (INES). Ten of these events were rated at level 1, others being of level 0:

- Common-cause failure in main steam line outer isolation valve actuator in 2009 (IRS report 8029)
- Stuck of the Olkiluoto unit 2 fuelling machine when removing spent fuel element from the reactor core, 2009
- Indicator light failure in the main control room leading to loss of one pump of shutdown cooling system, 2009
- Deficient leaktightness of piping penetrations in 2008 (IRS report 7997)
- Common-cause failure in emergency diesel starter motors in 2008 (IRS report 7935)
- Loss of safety-classified electrical equipment due to generator high voltage peak in 2008 (IRS report 7932)
- Control rod was driven against the administrative procedure set in the Operational Limits and Conditions, 2008
- Periodic tests of the some Olkiluoto unit 1 radiation monitoring instruments was not done within time limit given by the Operational Limits and Conditions, 2008
- Partially failed scram at the Olkiluoto unit 2 in 2007 (IRS report 7920)
- Qualification of some fuses was not done properly, 2007

Some of these incidents are described in more detail in Annex 2.

Operational experience feedback

According to the Section 24 of the Government Decree 733/2008, nuclear power plant operational experience feedback shall be collected and safety research results monitored, and both assessed for the purpose of enhancing safety. Safety-significant operational events shall be investigated for the purpose of identifying the root causes as well as defining and implementing the corrective measures. Improvements in technical safety, resulting from safety research, shall be taken into account to the extent justified on the basis of the principles laid down in Section 7 a of the Nuclear Energy Act.

Guide YVL 1.11 provides detailed requirements and administrative procedures for the systematic evaluation of operating experiences, and for the planning and implementation of corrective actions. Foreign operational occurrences have to be assessed as well, from the point of view of their safety significance. The licensees have developed the required procedures for analysing operating experiences. The procedures for root cause analyses are in use. Further attention is, however, still needed to avoid recurrence of incidents.

STUK verifies by means of inspections and by reviewing licensee's event reports that the activities of the licensees as regards incident evaluation are effective. When necessary, a special investigation team is appointed by STUK to evaluate a certain incident. The evaluation of foreign operational occurrences and incidents is based on the reports of the IRS Reporting System (IAEA/NEA) and on the reports of other national regulatory bodies. IRS reports are also evaluated by the licensees. Reports for the IRS System on safety-significant occurrences at Finnish nuclear power plants are written by STUK.

STUK has also participated in co-operation between international organisations such as the IAEA, the OECD/NEA and the EU, which exchange information on safety issues and operating events. Other forums that STUK uses to obtain information are WENRA, the VVER Forum and the NERS Forum as well as some bilateral agreements. A special exchange of information between Rostechnadzor and STUK on the operation of the Kola and Leningrad nuclear power plants and of Finnish nuclear power plants is also ongoing activity.

At the Loviisa NPP, VVER reactor operating experience is collected, screened and evaluated by a dedicated operating experience feedback group composed of engineers from the plant operation organisation and from Technical Support. The main information to be handled comes from WANO (World Association of Nuclear Operators) Moscow Centre which links all the VVER reactor operators. Additional reports are received from the IAEA, OECD/NEA and NRC (U.S. Nuclear Regulatory Commission). The activities of the operation experience feedback group are not limited only to VVER reactors. The plant managers of VVER-440 reactors run a so-called VVER Club with periodic meetings. The plant operation problems, modernisation, back-fitting, plant life management and safety questions are handled and experiences are exchanged in these meetings and in further individual contacts.

TVO has also an operating experience feedback group. This onsite group gives recommendations to the line organisation that makes decisions on eventual corrective actions. The industry operating experience from similar reactor types is followed by several means. The main sources of information are ERFATOM (the owners group for Nordic BWR operators), KSU (Swedish nuclear training centre), WANO and the Swedish Forsmark NPP. Information is also coming directly from several sources (IAEA and OECD/NEA, IRS), Loviisa power plant (e.g. operating experience meetings and reports), vendors (Westinghouse Atom, Alstom Power Sweden AB), component manufacturers, the WANO Network, BWROG (BWR Owners Group) and BWR Forum (FANP).

Management of spent fuel and radioactive waste on the site

Management of low and intermediate level waste from the production to the final disposal takes place at the NPP sites. Final disposal facilities for low and intermediate level waste are in operation at Loviisa and Olkiluoto sites. Since the disposal facilities are operated by the nuclear power plant operators, the technical feasibility and economic motivation to minimise the generation of radioactive waste are evident.

The detailed requirement for radioactive waste minimisation is included in the Guide YVL 8.3. It calls for a limitation of waste volumes in particular from repair and maintenance works, and segregation of wastes on the basis of activity. Clearance of wastes from regulatory control, prescribed in the Nuclear Energy Decree and in the Guide YVL 8.2, aims at limiting the volumes of waste to be stored and disposed of. The Guide YVL 6.2 provides for prevention of fuel failures, which also contributes to the limitation of activity accumulation in waste from reactor water cleanup systems.

The Guide YVL 8.3 also requires that besides the short-term radiation protection objectives, also the long-term properties of waste packages with respect to final disposal shall be taken into account in the conditioning and storage of waste. The Guide includes also more specific requirements for the conditioning and interim storage of wastes. The Guide YVL 8.1 calls for a waste type description, to be approved by STUK, for each category of reactor waste to be disposed of. In the description of waste type, the most important characteristics of waste with respect to the safety of disposal are defined.

Low and intermediate level waste

In 2007–2009 the policy to minimise the waste production at the Olkiluoto NPP has included the high quality requirements for the fuel, careful planning of the maintenance work and decontamination. The segregation and monitoring of the operational wastes have been effective, enabling the clearance from the regulatory control of waste below the clearance limits. In 2010, TVO transported moisture separator reheaters removed from Olkiluoto units 1 and 2 during refurbishment in 2005 and 2006 to Studsvik Nuclear AB for treatment.

At the Loviisa NPP, conditioning and disposal of liquid low and intermediate level waste will start after commissioning of the cementation plant. The target date for the start of operation is in spring 2011. The management of solid low and intermediate level waste has been developed by building new facilities for the treatment, activity monitoring and interim storage of waste. New facilities will be commissioned in 2010.

At the Loviisa NPP site, the repository for the low and intermediate level waste is located at the depth of 110 meters in granite bedrock. It consists of two tunnels for solid low level waste and a cavern for immobilised intermediate level waste.

The repository for the low and intermediate level waste at the Olkiluoto NPP site consists of two silos at the depth of 60 to 95 meters in tonalite bedrock, one for solid low level waste and the other for bituminised intermediate level waste.

The original plan presented in the construction licence application for unit Olkiluoto 3 was to dispose all the low and intermediate level waste in the existing repository in Olkiluoto. However, the waste packages of the conditioned intermediate level waste have different dimensions compared to the waste packages from operating units in Olkiluoto. Therefore TVO will in the operating licence application propose that the conditioned intermediate level waste is first stored on-site in the existing waste storage facility, and later disposed of in the extension of the repository. The solid low level waste from Olkiluoto unit 3 can be disposed of in the existing repository.

At the end of 2009, 6410 cubic meters of low and intermediate level operating waste has accumulated at the Olkiluoto NPP and 3180 cubic meters at the Loviisa NPP. About 80% of Olkiluoto waste and 62 % of Loviisa waste has been disposed of in the onsite repositories. Low and intermediate level waste not yet disposed of is stored inside the plants.

Decommissioning

The Guide YVL 1.0 requires that provision for a nuclear power plant's decommissioning shall be made already during the plant's design phase. One criterion when deciding the plant's materials and structural solutions shall be that volumes of decommissioned waste are to be limited. The Guide YVL 7.18 calls for selection of such construction materials that limit the degree of activation and spread of contamination and makes decontamination of surfaces feasible.

According to the Nuclear Energy Decree the licence applications must include the plans for decommissioning. The utilities are obliged to keep the decommissioning plans up-to-date and submit them to the Ministry every six years, last in 2008. STUK reviewed the plans and submitted its opinion to the Ministry in 2009.

The assumption in the decommissioning plan of the Loviisa NPP is that both units will be shut down after 50 years operation in 2027 and 2030. The dismantling starts immediately and lasts until 2035. Olkiluoto units 1 and 2 are planned to be shut down after 60 years operation in 2038 and 2040. The dismantling starts after 30 years delay. The final planning and building of disposal facilities will start already during the safe storage period and all together the decommissioning project will last about 15 years. The reason for delayed dismantling is the radiation protection of the personnel. Olkiluoto unit 3 is planned to shut down after 60 years operation in 2070's. The dismantling will start after the dismantling of the older units has been completed.

According to STUK's opinion to the Ministry, the decommissioning plans at this phase of the NPP operation are reasonably comprehensive and detailed. The decommissioning can be done as planned, and the plans are sufficient to be used in the cost estimations.

Spent fuel

Spent fuel from the Loviisa NPP was transported back to Russia until 1996. Amendment of the Nuclear Energy Act issued in 1994 requires that spent fuel generated in Finland has to be treated, stored and disposed of in Finland. Accordingly, spent fuel shipments to Russia were terminated, and the necessary extension of the wet type spent fuel storage facility was commissioned in 2001. The installation of the dense racks into the storage facility started in 2007 and continues until 2018. The capacity of the storage facility will be adequate for the total amount of the spent fuel 1100 tU allowed in the operating licence issued in 2007.

At Olkiluoto NPP the wet type spent fuel storage facility was commissioned in 1987. The current capacity about 1200 tU is adequate until 2014. TVO has started the construction works for enlarging the Olkiluoto interim storage in summer 2010. The extension includes construction of three new pools and it will be done according the updated safety requirements (Government decision 733/2008). Extension has been included in Olkiluoto NPP units 1 and 2 operating licence and has been handled as plant modification. STUK reviewed TVO's application and gave approval for construction during first half of the 2010. Extension has been planned to be ready in the end of 2013.

At the end of 2009, the spent fuel accumulation at the Olkiluoto NPP was about 1277 tons of uranium and at the Loviisa NPP about 477 tons of uranium.

The power companies Fortum and TVO established in 1995 the joint company Posiva to take care of spent fuel final disposal. Research, development and planning work for spent fuel disposal is in progress and the disposal facility is envisaged to be operational in about 2020. The Decision-in-Principle on the spent fuel disposal facility was made by the Government in 2000 and ratified by the Parliament in 2001. It covers the final disposal of the spent fuel from the Olkiluoto units 1 and 2 and Loviisa units 1 and 2. A separate Decision-in-Principle for the disposal of the spent fuel from the Olkiluoto unit 3 was made in 2002. The facility will be constructed in the vicinity of Olkiluoto NPP site. To confirm the suitability of the site, construction of the underground rock characterisation facility ONKALO was started in 2004. The excavation of ONKALO will be completed by the end of 2011.

In 2008 and 2009, Posiva submitted to the Government the applications for Decisions-in-Principle to expand the disposal facility for the planned NPP units Olkiluoto 4 and Loviisa 3. Government made a positive decision on 6 May 2010 regarding spent fuel from Olkiluoto 4 unit. Subsequently Parliament ratified the decision on 1 July 2010.

Safety regulation for spent fuel disposal is included in the Government Decree on the safety of disposal of nuclear waste 736/2008 and STUK's Guides YVL 8.4 and YVL 8.5.

A detailed description of spent fuel and radioactive waste management and related regulation is included in the Finnish National Report on the Safety of Spent Fuel Management and Radioactive Waste Management (STUK-B 96, October 2008).

In conclusion, Finnish regulations and practices are in compliance with Article 19.

ANNEX 1 List of main regulations

Legislation (as of 28th April 2010)

1. Nuclear Energy Act (990/1987), revised in 2008
2. Nuclear Energy Decree (161/1988), revised in 2008
3. Act on Third Party Liability (484/1972)
4. Decree on Third Party Liability (486/1972)
5. Radiation Act (592/1991)
6. Radiation Decree (1512/1991)
7. Government Decree on the Safety of Nuclear Power Plants (733/2008)
8. Government Decree on the Security in the Use of Nuclear Energy (734/2008)
9. Government Decree on Emergency Response Arrangements at Nuclear Power Plants (735/2008)
10. Government Decree on the Safety of Disposal of Nuclear Waste (736/2008)
11. Act on the Finnish Centre for Radiation and Nuclear Safety (1069/1983)
12. Decree on the Finnish Centre for Radiation and Nuclear Safety (618/1997)
13. Decree on Advisory Committee on Nuclear Safety (164/1988)

YVL Guides

General guides

Guide YVL 1.0 Safety criteria for design of nuclear power plants, 12.1.1996

Guide YVL 1.1 Regulatory control of safety at nuclear facilities, 10.2.2006

Guide YVL 1.2 Documents pertaining to safety control of nuclear facilities, 11.9.1995

Guide YVL 1.3 Mechanical components and structures of nuclear facilities. Approval of testing and inspection organizations, 17.3.2003

Guide YVL 1.4 Management systems for nuclear facilities, 9.1.2008

Guide YVL 1.5 Reporting nuclear facility operation to the Radiation and Nuclear Safety Authority, 8.9.2003

Guide YVL 1.6 Nuclear power plant operator competence, 5.10.2006

Guide YVL 1.7 Functions important to nuclear power plant safety, and training and qualification of personnel, 28.12.1992

Guide YVL 1.8 Repairs, modifications and preventive maintenance at nuclear facilities, 2.10.1986

Guide YVL 1.9 Quality assurance during operation of nuclear power plants, 13.11.1991

Guide YVL 1.10 Requirements for siting a nuclear power plant, 11.7.2000

Guide YVL 1.11 Nuclear power plant operating experience feedback, 22.12.1994

Guide YVL 1.12 INES classification of events at nuclear facilities, 16.1.2002

Guide YVL 1.13 Nuclear power plant outages, 9.1.1995

Guide YVL 1.14 Mechanical equipment and structures of nuclear facilities. Control of manufacturing, 4.10.1999

Guide YVL 1.15 Mechanical components and structures in nuclear installations. Construction inspection, 28.4.2008

Guide YVL 1.16 Regulatory control of nuclear liability insurances, 22.3.2000

Systems

Guide YVL 2.0 Systems design for nuclear power plants, 1.7.2002

Guide YVL 2.1 Nuclear power plant systems, structures and components and their safety classification, 26.6.2000

Guide YVL 2.2 Transient and accident analyses for justification of technical solutions at nuclear power plants, 26.8.2003

Guide YVL 2.4 Primary and secondary circuit pressure control at a nuclear power plant, 24.3.2006

Guide YVL 2.5 The commissioning of a nuclear power plant, 29.9.2003

Guide YVL 2.6 Seismic events and nuclear power plants, 19.12.2001

Guide YVL 2.7 Ensuring a nuclear power plant's safety functions in provision for failures, 20.5.1996

Guide YVL 2.8 Probabilistic safety analysis in safety management of nuclear power plants, 28.5.2003

Pressure equipment

Guide YVL 3.0 Pressure equipment of nuclear facilities, 9.4.2002

Guide YVL 3.1 Nuclear facility pressure vessels, 1.7.2005

Guide YVL 3.3 Nuclear facility piping, 26.6.2006

Guide YVL 3.4 Approval of the manufacturer of nuclear pressure equipment, 14.1.2004

Guide YVL 3.5 Ensuring the firmness of pressure vessels of a NPP, 5.4.2002

Guide YVL 3.7 Pressure equipment of nuclear facilities. Commissioning inspection, 26.9.2008

Guide YVL 3.8 Nuclear power plant pressure equipment. In-service inspection with non-destructive testing methods, 22.9.2003

Guide YVL 3.9 Nuclear power plant pressure equipment. Construction and welding filler materials, 5.11.2004

Buildings and structures

Guide YVL 4.1 Concrete structures for nuclear facilities, 22.5.1992

Guide YVL 4.2 Steel structures for nuclear facilities, 19.12.2001

Guide YVL 4.3 Fire protection at nuclear facilities, 1.11.1999

Other structures and components

Guide YVL 5.1 Nuclear power plant diesel generators and their auxiliary systems, 23.1.1997

Guide YVL 5.2 Electrical power systems and components at nuclear facilities, 24.6.2004

Guide YVL 5.3 Nuclear facility valve units, 28.4.2008

Guide YVL 5.5 Instrumentation systems and components at nuclear facilities, 13.9.2002

Guide YVL 5.6 Air-conditioning and ventilation systems and components of nuclear facilities, 25.11.2004

Guide YVL 5.7 Nuclear facility pump units, 28.4.2008

Guide YVL 5.8 Hoisting and transfer functions at nuclear facilities, 26.9.2008

Nuclear materials

Guide YVL 5.1 Nuclear power plant diesel generators and their auxiliary systems, 23.1.1997

Guide YVL 5.2 Electrical power systems and components at nuclear facilities, 24.6.2004

Guide YVL 5.3 Nuclear facility valve units, 28.4.2008

Guide YVL 5.5 Instrumentation systems and components at nuclear facilities, 13.9.2002

Guide YVL 5.6 Air-conditioning and ventilation systems and components of nuclear facilities, 25.11.2004

Guide YVL 5.7 Nuclear facility pump units, 28.4.2008

Guide YVL 5.8 Hoisting and transfer functions at nuclear facilities, 26.9.2008

Radiation protection

Guide YVL 7.1 Limitation of public exposure in the environment of and limitation of radioactive releases from a nuclear power plant, 22.3.2006

Guide YVL 7.2 Assessment of radiation doses to the population in the environment of a nuclear power plant, 23.1.1997

Guide YVL 7.3 Calculation of the dispersion of radioactive releases from a nuclear power plant, 23.1.1997

Guide YVL 7.4 Nuclear power plant emergency preparedness, 9.1.2002

Guide YVL 7.5 Meteorological measurements of a nuclear power plant, 28.5.2003

Guide YVL 7.6 Monitoring of discharges of radioactive substances from a nuclear power plant, 22.3.2006

Guide YVL 7.7 Radiation monitoring in the environment of a nuclear power plant, 22.3.2006

Guide YVL 7.8 Environmental radiation safety reports of a nuclear power plant, 22.3.2006

Guide YVL 7.9 Radiation protection of workers at nuclear facilities, 21.1.2002

Guide YVL 7.10 Monitoring of occupational exposure at nuclear facilities, 29.1.2002

Guide YVL 7.11 Radiation monitoring systems and equipment of a nuclear power plant, 13.7.2004

Guide YVL 7.18 Radiation safety aspects in the design of a nuclear power plant, 26.9.2003

Radioactive waste management

Guide YVL 8.1 Disposal of low and intermediate level waste from the operation of nuclear power plants, 10.9.2003

Guide YVL 8.2 Clearance of nuclear waste and decommissioned nuclear facilities, 18.2.2008

Guide YVL 8.3 Treatment and storage of low and intermediate level waste at a nuclear power plant, 29.6.2005

Guide YVL 8.4 Long-term safety of disposal of spent nuclear fuel, 23.5.2001

Guide YVL 8.5 Operational safety of a disposal facility for spent nuclear fuel, 23.12.2002.

The guides are available online at **www.edilex.fi/stuklex/en/** (not all published in English).

ANNEX 2 Finnish nuclear power plants

Loviisa NPP

The Loviisa plant comprises of two VVER units that are operated by Fortum Power and Heat Oy (Fortum). The plant units were connected to the electrical grid in February 8, 1977 (Loviisa 1) and November 4, 1980 (Loviisa 2). The nominal thermal power of both of the Loviisa units is 1500 MW (109% as compared to the original 1375 MW). The increase of the power level was licensed in 1998. The Operating Licences of the units are valid until the end of 2027 (unit 1) and 2030 (unit 2). According to the conditions of the licences, two periodic safety reviews are required to be carried out by the licensee (by the end of the year 2015 and 2023).

Most significant plant modifications at the Loviisa NPP during the plant lifetime

Several plant changes have been carried out during Loviisa NPP plant lifetime. The most important projects since the plant commissioning have been modifications made for protection against fires, modifications based on the development of the PRA models, severe accident mitigation programme, reactor uprating, and contruction of training simulator, interim storage for spent fuel and repository for reactor operational waste.

In some of the earliest modifications in 1982, a hydrogen removal system was installed in the containment building in order to eliminate the risk of explosion during an accident when hydrogen is released from the core. The system consisted of 60 glow plugs that can ignite a controlled hydrogen burn.

In 1993, strainer area in the floor sumps of the emergency cooling system and the containment spray system was significantly enlarged by new design, and the sump systems were improved so as to provide more reliable pumping of the water accumulated in the two sumps during a loss of coolant accident (when the emergency make-up water tank is empty) back into the reactor and to the spray nozzles. The sumps were equipped with several hundreds of strainer units, a nitrogen flush system to blow any insulation debris off the strainers, and control instrumentation. The amount of debris the strainer system can cope with increased ten-fold.

In connection with the PRISE project in 1994–1995 (protection from primary to secondary leaks), the plant protection system was modified to provide automatic isolation of the damaged steam generator at high water level (the steam and feed water lines are closed), and to stop the respective reactor coolant pump. The aim was to protect the steam line from water hammer. Also new measuring equipment, based on the detection of nitrogen-16 isotope, was installed in the steam lines in order to ensure the detection of any leaks from the primary circuit.

Protection against fires at the Loviisa NPP

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the layout design of the Loviisa plant. Therefore, fire compartments were not implemented so that the plant safety functions could be maintained during all fire situations considered possible. For this reason the significance of an active fire fighting (fire alarm and extinguishing systems as well as operative fire fighting) is important along with structural fire protection arrangements.

Fire safety has been improved with several measures at the Loviisa plant after its commissioning. These measures have been implemented in various fields of fire protection. As a result, the plant safety against the effects of fires has been essentially improved.

For a provision against oil fires in the turbine hall several measures have been taken. Fire insulators of the load-bearing steel structures of the turbine building have been installed. The turbine hall has been equipped with an automatic sprinkler system and the significant parts of the turbines have been protected. Later on, the fire wall of the turbine hall has been built up to protect components important to reactor decay heat removal. Furthermore, the additional emergency feedwater system has been built for the case that all feedwater and emergency feedwater systems would be lost in a turbine hall fire. At the Loviisa NPP the decay heat removal systems are in the turbine hall. That´s why a separate building for additional decay heat removal system outside turbine hall was built in 2005. The new system is needed for cooling the plant to cold shutdown, if normal systems are not operable.

The main transformers have been protected with a sprinkler system which essentially reduces the risk that a fire would spread into the surrounding buildings, especially into the turbine hall. The risk to lose the AC-power (station black-out) during transformer fires has been reduced by protecting the diesel generators against fires. The 110 kV net connection has been physically separated from the 400 kV connection so that the loss of both connections as a result of a transformer fire is improbable. Several improvements against fires have been done in off-site power supply arrangements and in diesel generators. The original fire water pumps are supplied only from the off-site electrical network. Therefore, an additional fire water pump station has been constructed at the plant. It has been equipped with diesel-driven fire water pumps and with a separate fire water tank. Fire water piping and fire extinguishing systems as well as their coverage have been improved. A new addressed fire alarm system was completed in 1999 at Loviisa 1 and in 2001 at Loviisa 2. Several structural improvements for fire safety have been done, or are under design.

The level of the operative fire protection has been improved by establishing a plant fire fighting crew which is permanent, constantly ready to depart and has the proper equipment. As regards fire protection and fire risks also plant instructions have been complemented.

Severe Accident Management implementation at Loviisa NPP

The Loviisa severe accident programme, which includes plant modifications and severe accident management procedures, was initiated in the end on 1980's in order to meet the requirements of STUK. For Loviisa NPP, the severe accident management approach focuses on ensuring the following top level safety functions:

- depressurisation of the primary circuit
- absence of energetic events, i.e. hydrogen burns
- coolability and retention of molten core in the reactor vessel
- long term containment cooling
- ensuring subcriticality
- ensuring containment isolation.

The developed severe accident management (SAM) strategy lead to a number of hardware changes at the plant as well as to new severe accident guidelines and procedures.

The primary system depressurisation is an interface action between the preventive and mitigation parts of SAM. If the primary feed function is operable, the depressurisation may prevent the core melt (primary system cooling by feed and bleed). If not, it sets in motion the mitigation actions and measures to protect the containment integrity and mitigate large releases. Manual depressurisation capability has been designed and implemented through motor-operated high capacity relief valves. Depressurisation capacity will be sufficient for bleed & feed operation with high-pressure pumps, and for reducing the primary pressure before the molten corium degrades the reactor vessel strength. Depressurisation is to be initiated from indications of superheated temperatures at core exit thermocouples. The depressurisation valves were installed at the same time with the replacement of the existing pressuriser safety valves in 1996.

The cornerstone of the SAM strategy for Loviisa is the coolability of corium inside the reactor pressure vessel (RPV) through external cooling of the vessel. Since the RPV is not penetrated, all the ex-vessel phenomena such as ex-vessel steam explosions, direct containment heating and core-concrete interactions can be excluded. Some of the design features of the Loviisa plant make it most amenable for using the concept in-vessel retention of corium by external cooling of the RPV as the principle means of arresting the progress of a core melt accident. Such features include the low power density of the core, large water volumes both in the primary and in the secondary side, no penetrations in the lower head of the RPV, and ice condensers which ensure a passively flooded cavity in most severe accident scenarios. On the other hand, if in-vessel retention was not attempted, showing resistance to energetic steam generation and coolability of corium in the reactor cavity could be laborious for Loviisa NPP, because of the small, water filled cavity with small floor area and tight venting paths for the steam out of the cavity.

An extensive research programme regarding the thermal aspects was carried out by Fortum. The work included both experimental and analytical studies on heat transfer in a molten pool with volumetric heat generation and on heat transfer and flow behaviour at the RPV outer surface. Based on experiments, the in-vessel retention concept for Loviisa was finalised. STUK approved the conceptual design in December 1995. The modifications were completed in 2002. The most laborious one of them was the modification of the lower neutron and thermal shield such that it can be lowered down in case of an accident to allow free passage of water in contact with the RPV bottom. Also a strainer facility was constructed in the reactor cavity in order to screen out possible impurities from the coolant flow and thereby prevent clogging of the narrow flow paths around the RPV.

Based on plant-specific features, the only real concern regarding potential energetic phenomena is due to hydrogen combustion events. The Loviisa NPP reactors are equipped with ice-condenser containments, which are relatively large in size (comparable to the volume of typical large dry containments) but have a low design pressure of 0.17 MPa. The ultimate failure pressure has been estimated to be well above 0.3 MPa. An intermediate deck divides the containment in the upper (UC) and lower compartments (LC). All the nuclear steam supply system components are located in the lower compartment and, therefore, any release of hydrogen will be directed into the lower compartment. In order to reach the upper compartment, which is significantly larger in volume, the hydrogen and steam have to pass through the ice-condensers.

In the 1990's an extensive research programme was carried out at Fortum to assess the reliability and adequacy of the existing igniters system. The experiments and the related numerical calculations demonstrated that the global convective loop around the containment for ensuring well mixed conditions will be created and maintained reliably provided that the ice-condenser doors will stay open. A new hydrogen management strategy for Loviisa was formulated which concentrates on two functions: ensuring air recirculation flow paths to establish a well-mixed atmosphere (opening of ice condenser doors) and effective recombination and/or controlled ignition of hydrogen. Plant modifications included installation of autocatalytic hydrogen recombiners, modifications in the igniters system (igniters were removed from the upper compartment and left only in the lower compartment) and a dedicated system for opening the ice-condenser doors. The modifications were completed in 2003.

The studies on prevention of long term over pressurisation of the containment showed that the concept of filtered venting was not possible at the Loviisa NPP because the capability of the steel liner containment to resist subatmospheric pressures is poor. An external spray system was then designed to remove the heat from the containment in a severe accident when other means of decay heat removal from the containment are not operable. Due to the ice condenser containment, the time delay from the onset of the accident to the start of the external spray system is long (18–36 hours). Thus the required heat removal capacity is also low, only 3 MW (fraction of decay power is still absorbed by thick concrete walls). The system is started manually when the containment pressure reaches the design pressure 1.7 bar. Autonomous operation of the system independently from plant emergency diesels is ensured with dedicated local diesel generators. The active parts of the system are independent from all other containment decay heat removal systems. The containment external spray system was implemented at the two units in 1990 and 1991.

The SAM strategy implementation included also a new, dedicated, limited scope instrumentation and control system for the SAM systems, a dedicated AC-power system and a separate SAM control room which is common to both units. These were implemented mainly in year 2000 for Loviisa unit 1 and in 2002 for Loviisa unit 2.

In addition to the hardware modifications, severe accidents guidance for the operating personnel has been implemented. It consists of SAM procedures for the operators and of a so-called Severe Accident Handbook for the Technical Support Team. The SAM procedures are entered after a prolonged uncover of the reactor core indicated by highly superheated core exit temperatures. The procedures are symptom oriented and their main objective is the protection of containment integrity through ensuring the top level severe accident safety functions.

Modernisation and power uprating of Loviisa NPP in 1994–1997

The key aspects in the project for the modernisation and power uprating of Loviisa NPPs were to verify the plant safety, to improve production capacity and to give a good basis for the extension of the plant's lifetime to 50 years, which corresponds to the additional 20 years of operation applied for both units of the Loviisa NPP in 2006.

In the first phase, before starting the project, a feasibility study for uprating of the reactor thermal power was carried out. The main result was in short that no technical or licensing issues could be found which would prevent the raising of the reactor thermal output up to 1500 MW from the original level of 1375 MW. The feasibility study gave also a good picture of the necessary plant modifications. It focused on the following tasks: the optimisation of the power level and definition of the new parameters of the main process, reactor core and fuel studies, including RPV irradiation embrittlement, safety analyses and licensing, the main components and systems, and project planning and risk assessment.

The reactor power uprating from 1375 MW to 1500 MW was planned on the basis of optimising the need for major plant modifications. In the primary side and the sea water cooling system, the mass flow rates were not affected, but the temperature difference has been increased in proportion to the power upgrading. In the turbine side, the live steam and the feedwater flow rate were increased by about 10%; the live steam pressure was not changed.

The reactor fuel loading was considered on the basis of the previous limits set for the maximum fuel linear power and fuel burn-up. The increase in the reactor thermal output was carried out by optimising the power distribution in the core and the power of any single fuel bundle was not increased above the maximum level before power upgrading. In parallel with this work, more advanced options related to the mixing rate of the cooling water in the fuel subchannels and the increasing of fuel enrichment were investigated. The dummy elements installed on the periphery of the core at the Loviisa units 1 and 2 were preserved to minimise irradiation embrittlement of the reactor pressure vessel.

The VVER 440 design margins in the primary side are rather large and the hardware modifications needed there were quite limited. Replacement of the pressuriser safety valves was indicated already during the feasibility study as a necessary measure because of the power upgrading. Most of the other substantial measures in the primary side were carried out on the basis of the continuing effort to maintain and raise the safety level of the plant, and they were not directly included in the power upgrading.

It was necessary to carry out more extensive measures in the turbine plant and to the electrical components. Steam turbines were modified to a higher steam flow rate. Because of these measures, also the efficiency and operation reliability has improved. Certain modifications were carried out in the electrical generators and the main transformers to ensure reliability in continuous operation with the upgraded power output.

The implementation of the modernisation project was carried out in co-operation between Loviisa NPP and Fortum Nuclear Services (former Fortum Engineering). In addition, many other organisations such as the Technical Research Centre of Finland (VTT) participated in the work. The last step in the process to uprate the reactor thermal power was the long-term trial run to verify the main process parameters as well as plant operation in both steady state and transient situations. The first trial run at 103% reactor power could be started in January 1997. Test runs continued step by step during the year, and the last transient test at final reactor power 109% was completed successfully in December 1997. Transient tests defined in the test programme were performed with a reactor thermal power of 105% and 109%. The test results corresponded very well with all analyses and calculations. All the acceptance criteria for the tests were fulfilled. Measures to improve the efficiency of the steam turbines continued in the annual maintenance outages until the year 2002.

STUK was closely involved at every stage of the project, from the early planning of the concept to the evaluation of the results from the test runs. STUK examined all the modification plans that might be expected to have an impact on plant safety. Individual permits were granted stage by stage, based on the successful implementation of previous work.

The renewal of the operating licence for the increased reactor power was carried out according to the nuclear safety legislation. First the Ministry of Employment and the Economy (former Ministry of Trade and Industry) gave a permission to make plant modifications and test runs with upgraded reactor power under the existing operating licence and under the control of STUK. Then the assessment of the environmental impact (EIA-procedure) of the project was carried out. STUK approved the Final Safety Analyses Report (FSAR), the safety-related plant modifications, and the test programmes and the results. Finally the Government granted the renewed operating licence in April 1998. The licence was awarded to 1500 MW nominal reactor thermal power until the end of the year 2007.

The revision of emergency operating procedures (2000–2005)

The emergency operating procedures of Loviisa nuclear power plant were revised in the so called HOKE project, launched in 2000. The project encompassed the drawing up of diagnosis procedures for transients and emergencies arising from primary and secondary leaks, procedures for operators and the safety engineer as well as action sheets for onsite measures.

In accordance with the new procedures, nuclear power plant operators follow their own separate procedures and initiate the necessary actions in their fields of responsibility in the event of an emergency or a transient. The shift manager co-ordinates these actions and reviews the main actions and parameters using his own procedures. The safety engineer in parallel with the operators independently oversees safety functions using separate procedures to ensure that plant behaviour is as planned.

The revised procedures consist of guidelines and instructions presented as flow charts. The guidelines define strategy and give grounds for operator actions during emergencies and transients. It serves as a basis for actual control room procedures containing operator procedures. The guidelines are used for training purposes as well.

The validation and verification of the procedures and their background material ascertains authenticity of the procedures i.a. by comparison with the plant and by simulator tests. Verification authenticates i.a. correlation and functioning of the new procedures with other plant procedures. The project included training given to the control room personnel of the Loviisa plant in the use of the new procedures. Due to the revision's significance STUK required that shift supervisors and operators working in the control room have given shift-specific proof of workmanship prior to the introduction into use of the revised procedures.

In December 2005, STUK authorised the introduction into service of the revised emergency operating procedures.

Latest plant modifications at the Loviisa NPP (2008–2010)

Replacement of high-pressure safety injection system pumps

Two of the four pumps in the high-pressure safety injection system of both plant units were replaced with new types. The reason for changing the pump type was the poor availability of spare parts and an improvement in the functional reliability of the system. In 2004, STUK approved the power company's conceptual plan and time schedule for replacing the pumps. In line with the schedule, two pumps were replaced during the annual maintenance outage of Loviisa 1 in 2008, one for both system redundancies, and the respective pipeline modifications were also carried out. The corresponding work was carried out at Loviisa 2 during the 2006 annual maintenance outage.

Construction and commissioning of a liquid waste solidification facility

A solidification facility for liquid radioactive waste has been constructed on the Loviisa plant site. The solidification facility processes the evaporation residues generated at the power plant and the radioactive ion exchange resins from the purification filters. The power company initiated the commissioning phase of the solidification facility implementation project during 2006 by carrying out system- and plant-level tests using inactive substances. Plant-level tests continued in 2008 using radioactive evaporation residues and in 2009 with radioactive ion exchange resins. There will be some plant modifications done based on the findings during the commissioning phase after which the commissioning can be finilised and the operation may be started in the facility after approval of STUK.

Latest incidents at the Loviisa NPP (2008–2010)

Loviisa 2, deficiency in the reactor protection system

It was observed at Loviisa 2 on 12 December 2008 that a simulation had been left in the reactor protection system indicating that three reactor coolant pumps were in operation. As a result, the reactor protection system would not have been informed if these pumps had stopped and the reactor trip signal, triggered if four or more reactor coolant pumps had stopped, would not have been activated. The condition was in non-compliance with the Operational Limits and Conditions. The simulations were immediately removed when the incorrect setup was detected. The event caused no danger to the environment or the personnel, but it weakened the operability of the reactor protection system.

The error had not been detected in connection with the monthly reactor protection system tests. No physical inspections of the couplings in the I&C cabinets in question are carried out during normal operation of the plant. The error was revealed as an instrumentation technician performed measures related to a different test at the cabinets in question. Apparently, the simulations had remained active after the testing completed in the annual maintenance outage that ended in October. The event indicates a significant deficiency in practices at the Loviisa plant: the protection system had been made unavailable without adequate documentation. For this reason, simulations were left undetected and remained in place when the plant was started up. The unavailability was also not possible to detect in the periodic tests carried out monthly at the plant.

The reactor trip command would not have worked if the reactor coolant pumps had stopped due to, for example, a power failure. In such a case, the reactor trip would have occurred a little later, resulting from increased reactor pressure or coolant temperature. This would have led to a momentary deterioration of reactor cooling, and an increase in pressure. However, based on safety analyses carried out for the plant unit, there would have been no risk of fuel damage. The stopping of reactor coolant pumps with no resulting reactor trip is included in the safety analyses that the plant unit's operating licence is based on. The power company investigated the event and performed additional analyses to gain a more detailed understanding of the reactor behaviour in these conditions.

On the seven-level International Nuclear Event Scale (INES), the event was rated at level 1.

Periodic safety reviews at the Loviisa NPP

During the years 1996–1998 the overall safety review of the Loviisa plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Employment and the Economy (former Ministry of Trade and Industry) in March 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The latest overall safety review of the Loviisa plant took place in 2005–2007 in connection of the relicensing of the operation of the plant. The operating licence application was addressed to the Government and was handled by the Ministry of Employment and the Economy. Fortum filed the application to the Ministry of Employment and the Economy in November 2006. Legislative and regulative requirements for the application of the operating licence are described in the Nuclear Energy Decree (161/1988) Sections 33, 34, 36 and in the Guide YVL 1.1 Regulatory control of safety at nuclear facilities.

The Loviisa plant was reaching its original design age in 2007–2010, but the technical and economical lifetime of the plant is estimated to be at least 50 years according to the current knowledge of the plant ageing. Due to consistent plant improvements, the safety level of the plant has been increased as shown by the probabilistic risk assessment (PRA).

Based on the application, STUK carried out a comprehensive review of the safety of the Loviisa plant. The review was completed in July 2007 when STUK provided the Ministry of Employment and the Economy with it's statement on the safety of the plant. The Finnish Government granted in July 2007 to Fortum new licences for unit 1 until the end of 2027 and for unit 2 until the end of 2030. The length of the operating licences corresponds to the current goal for the plant's lifetime, which is 50 years. Two periodic safety reviews (by the end of the year 2015 and 2023) are to be carried out by the licensee as a licence condition.

The statement of safety included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK. Based on the assessment, STUK considered that the Loviisa Nuclear Power Plant meets the set safety requirements for operational nuclear power plants but there are some reservations related to the redundancy and separation of components needed for performing safety functions. These reservations are originating from the design basis laid down during the 1970s. However, substantial modernisations have been carried out at the Loviisa NPP since its commissioning to improve safety. Risk factors have been systematically identified and eliminated using operating experience, research and development and probabilistic risk analysis. Fortum has many ongoing projects for enhancing safety. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act. As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the prerequisites for safe operation of Loviisa NPP have been met.

Planned and ongoing activities to improve safety at the Loviisa NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Loviisa nuclear power plants since its commissioning and there exists no urgent need to upgrade the safety of this plant in the context of the Convention.

For continued safe operation, plant improvement projects are still necessary. The largest ongoing investment is the complete renewal of the plant I&C system, which is scheduled to be completed by 2014.

Reactor pressure vessel relicensing

Plant lifetime management includes credible procedures for following the plant ageing. The conditions of components which are practically impossible to be replaced by new ones (pressure vessel, steam generators, etc.) are monitored most actively.

Several modifications have been made at the both Loviisa plant units to reduce the risk of reactor vessel brittle fracture. In 1980, 36 fuel bundles at the outer edge of the reactor core were replaced with by stainless steel elements (dummies) to reduce the risk of reactor vessel brittle fracture in the long term. The purpose was to reduce the impact of neutron radiation on the reactor pressure vessel thereby preventing premature embrittlement of the pressure vessel. The reactor pressure vessel of Loviisa unit 1 was heat treated in 1996 to restore quality of one of the mostly affected weldings.

Fortum stated during the last operating licence renewal process that the brittle fracture risk can be managed until the end of the 50 years plant lifetime. The use of the reactor pressure vessel at the Loviisa unit 1 is licensed until the outage 2012 and at the Loviisa unit 2 until the outage 2010. The licence renewal of the reactor pressure vessels required Fortum to update the safety analyses. The application to extend the operation of the pressure vessel at the Loviisa unit 2 until the end of 2030, i.e., to the end of the plant unit's operating licence, is presently at STUK's review.

I&C renewal project at Loviisa NPP

I&C systems of the Loviisa nuclear power plant units are being renewed stepwise in a project that will continue until the year 2014. Some modifications will also be made to the functions of the plant systems. Furthermore, a new emergency control room will be provided for each unit to replace the emergency control panels currently located mutually in the main control rooms of the other unit. I&C renewal will be implemented in several project phases so that each phase will be adopted during maintenance outages.

Preliminary planning of the renewal project started several years ago and in the beginning of 2005 the licensee signed the delivery contract with the consortium of Framatome and Siemens. New buildings at the plant site have been constructed and will accommodate the main equipment of the safety and operational I&C. The first phase of the project included e.g. the renewal of the reactor preventive protection I&C and was implemented in the outage 2008 at Loviisa unit 1 and at Loviisa unit 2 in the outage 2009.

Olkiluoto NPP

The Olkiluoto plant comprises of two BWR units that are operated by Teollisuuden Voima Oyj (TVO). The plant units were connected to the electrical network in September 2, 1978 (Olkiluoto 1) and February 18, 1980 (Olkiluoto 2). The nominal thermal power of both Olkiluoto units is 2500 MW, which was licensed in 1998. The new power level is 115.7% as compared to the earlier nominal power 2160 MW licensed in 1983. The original power level of both units was 2000 MW. The Operating Licences of the units are valid until the end of 2018. According to the conditions of the licences, the licensee carried out a periodic safety review and submitted it to the regulator in the end of 2008.

Most significant plant modifications at the Olkiluoto NPP during the plant lifetime

Several plant changes have been carried out during Olkiluoto NPP plant lifetime. The most important projects since the plant commissioning have been two reactor upratings, severe accident mitigation programme, modifications based on the develoment of the PRA models, contruction of training simulator, interim storage for spent fuel and repository for reactor waste, and investigation programme for disposal of spent fuel. The first power uprating project was carried out in 1983–1984. Thermal power was uprated from 2000 MW to 2160 MW (8%). The plant modifications included for example a new relief valve that was installed in the reactor primary system, changes in the reactor protection system, and increase of cooling capacity of some heat exchangers.

Severe Accident Management implementation at the Olkiluoto NPP

Several new research programmes were launched in the beginning of 1980's, whose objective was both to clarify the character and magnitude of loads arising from a severe accident and to find means for controlling the loads on the containment. The main provisions for severe accident management were installed at the Olkiluoto units 1 and 2 during the SAM project which was finished in 1989. The measures implemented were

- containment overpressure protection
- containment filtered venting
- lower drywell flooding from wetwell
- containment penetration shielding in lower drywell
- containment water filling from external source
- containment instrumentation for severe accident control
- Emergency Operating Procedures for severe accidents.

The means for managing severe accidents had to be adjusted to the existing design, and so an optimal implementation of all chosen solutions was not possible. Subsequent development of the accident management procedures and additional minor plant modifications at Olkiluoto plant have taken place during the years after that when new aspects on the issue have emerged.

To secure depressurisation of the reactor primary system in severe accident situations and to prevent a new pressurisation of the reactor, two valves of the relief system were modified. It is now possible to keep the valves open with the help of nitrogen supply or water supply from outside the containment.

One of the most significant deficiencies at the Olkiluoto plant containments, from the standpoint of controlling severe accidents, has been the small size of the containment, which may cause the containment to pressurise due to the hydrogen and steam generation during an accident,. Another deficiency is the location of the reactor pressure vessel inside the containment, which is such that the core melt erupting from the pressure vessel may expose the structures and penetrations that ensure the tightness of the containment, to pressure loads and thermal stresses. To eliminate these deficiencies, the containment was e.g. provided with a pressure relief system. Gases that pressurise the containment can be removed through a filter designed for the purpose, if the pressure inside the containment threatens to increase too much. The part of the containment underneath the reactor pressure vessel can be flooded with water in order to protect the containment bottom and penetrations from the thermal effect of core melt. Some penetrations of the containment have been protected from the direct effect of core melt also by structural means. To ensure the cooling of reactor debris, the plant units are also provided with a water filling system, by the means of which the water level inside the containment can be raised all the way to the same level with the upper edge of the reactor core.

The cooling of reactor core melt and the protection of containment penetrations requires that the lower dry well of the containment is flooded at such an early stage of the accident that if the pressure vessel melts through, the erupting core melt falls into a deep water pool. When the core melt falls into the water a so-called steam explosion, which causes a strong and quickly propagating pressure wave in the water pool, may occur. A lot of research has been done on steam explosions. The results show that the core melt discharged through the pressure vessel cools down as it travels through the water pool and cannot create a steam explosion. However, the structures of the lower equipment hatch have been enforced to decrease the risk for loss of containment integrity due to loads caused by steam explosions.

Research results have demonstrated that in unfavourable conditions iodine may form organic compounds that are not easily absorbed in the containment or in the filter. Such conditions may occur at the Olkiluoto plant, if the water inside the containment is acidified due to chemicals released during the accident. Organic iodine may also be generated in the primary circuit, if iodine reacts with the hydrocarbons that are released, when the boron carbide contained in the control rods becomes oxidised during the core damage. To improve the possibilities for retaining organic iodine in the filtered venting system, chemicals have been added to the water in the scrubber tank of the system. To minimise the formation of organic iodine, it is also possible to control the pH of the containment water volume by a specific system. The function of the system is based on addition of NaOH to the fire fighting water reservoir which is used for filling of the containment in post-accident conditions. The lower drywell will be flooded from the wetwell prior to the NaOH supply and the lower drywell water pool pH will be kept above 7.

Protection against fires at the Olkiluoto NPP

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the existing Olkiluoto plant. Fire safety has been improved in different areas of the fire protection at the existing Olkiluoto plant after commissioning. Although the loss of external electrical supply has been taken into account in the plant design, the plants were provided with e.g. a new start-up transformer, based on the experience gained from the fire of the electric supply unit in 1991, to improve the independency of plant's external grid connections. Furthermore, the main transformers, in-house transformers and start-up transformers are protected with a sprinkler extinguishing system, which reduces essentially the risks arising from transformer fires. The use of halon is forbidden in Finland after the year 1999 with the exception of some special items. Due to this the halon extinguishing systems at the existing Olkiluoto plant were replaced with other extinguishing systems by the year 2000. Fire risks have been assessed in a probabilistic risk assessment that concentrates on fire issues. Based on this the fire protection of cables, that are crucial to safety, have been improved at the entire plant. On the basis of the probabilistic risk assessment these improvements reduce the risks arising from fires considerably.

Modernisation and power uprating of Olkiluoto NPP in 1994–1998

The main goals of the modernisation project at the Olkiluoto NPP were the reviewing of safety features and enhancing safety, when feasible, improving the production related performance, finding factors limiting the plant lifetime and eliminating them, when feasible, and enhancing the expertise of the own staff and improving productivity. In order to achieve the safety goal, the existing plant design was reviewed and compared by the TVO to the present and foreseeable safety requirements. Compliance with the European Utility Requirements (EUR) was also reviewed. The feasibility of fulfilling new requirements set for the new nuclear power plants was considered case by case. The living PRA model of the plant was utilised in this context.

The most important safety related modifications included in the modernisation programme are listed below:

- Reactor pressure relief system was diversified by installing two additional relief valves.
- ATWS behaviour was improved by modifying some trip signals and making boron injection automatic and more effective.
- Additional severe accident mitigation measures were implemented.
- Earthquake resistance of the plant was checked and related modifications were made.
- Partial scram function was strengthened.
- Generator breaker was replaced with a new one, which is able to break also short circuit current.
- Protection against frazil ice at the seawater intake was improved.
- Protection against snowstorms at the air intake of the emergency diesels was improved.

The modernisation programme as a whole reduced the severe core damage frequency estimate by a factor of three.

The radiation exposure of the population was reduced in accordance with the ALARA principle. Liquid releases were reduced by a factor of ten by improving the liquid waste handling systems. Also occupational doses were reduced. In practice, this meant minimising the cobalt content in the primary circuit. Renewal of steam dryers reduced the occupational doses remarkably, because the moisture of the steam was reduced.

The development of the BWR technology, margins revealed by operational experience, and plant modifications due to other reasons made also power uprating possible. Thermal power was uprated from 2160 MW to 2500 MW (15.7%). The most important changes were made in fuel technology. The operation was changed from with 8×8 bundles to 10×10 bundles. The new bundles have 40 percent lower average linear heat rating than the old ones. Some additional design changes implemented due to the uprating were the increasing of inertia of the main circulation pumps electrically, steam separators replacement, high-pressure turbine and feed water system modifications, decay heat removal system capacity increasement, and generator and main transformers replacements. The low pressure turbines were also replaced and in that way about 30 MW additional production capacity in each unit was achieved.

The modernisation programme of the Olkiluoto plant units 1 and 2 was started in 1994 and completed in 1998. The installations were performed during the refuelling outages of the years 1996–1998. Some later installations were realised during outages in 1999. In spite of large modifications the refuelling outage times were reasonable, between 15 and 20 days. The test programme was quite the same as in the case of a new plant.

Licensing steps related to the modernisation programme included an uprated Safety Analysis Report (PSAR, for example) and an uprated Probabilistic Safety Assessment (level 1 PSA), which were reviewed and approved by STUK. Design modifications and test runs were accepted by STUK before implementation. The Final Safety Analysis Report (FSAR) and the related Topical

Reports were rewritten. It meant also that almost all transient and accident analyses were redone taking into account the uprated power level and modified plant design. The FSAR and Topical Reports were submitted to STUK at the end of 1996. An operating licence renewal application, covering design modifications and the power uprating, was submitted to the Government at the end of 1996. The licence was granted in 1998. The power uprating was reviewed also according to the Environmental Impact Legislation.

Modernisation and power uprating project contained several safety, ageing and efficiency remedies. Mostly influences of modifications have been positive. A negative finding has been a slight increase of steam moisture. To improve this in both units steam dryers were replaced in outages 2005–2007. Another slightly negative finding was increase of condensate clean up temperature, which decreased the life cycle of clean up resins. To avoid this problem the location of condensate clean up system was changed in the process. In this context even the first LP-preheaters were replaced and modernised.

The modernisation of turbine plant was continued with replacement of steam reheater moisture separators (MSR). They were replaced with modern two stage MSR's. This replacement required modernisation of HP-turbine as well. These replacements were performed in outages 2005 and 2006. In the same outages the I&C system of the turbine plant process was be replaced with a modern digital one.

Turbine plant process automation system renewal (2004–2006)

A new computerised turbine plant automation system was installed in the Olkiluoto unit 2 in 2005 annual maintenance outage (equivalent modification was performed at Olkiluoto unit 1 in 2006). One reason to switch from analogue to programmable technology was the obsolescence the old system. In addition, the modifications made in the turbine plant process in 2005, and in 2006, required some additional modifications to the automation system. The new system improves information management and control of the turbine plant as well as facilitates component maintenance. Another system renewal objective is increased reliability and reduced susceptibility to malfunctions by added redundancy.

The new automation system is implemented by programmable technology. This allows an increased number of process status measurements and versatile information handling possibilities. As regards turbine automation, it facilitates for turbine operators improved information management, process control at operating work stations, trend monitoring and setting of safety limits. Safety limit settings enable turbine operator reaction to even minor process changes. The control desk for the turbine side in the control room was replaced with a safety function control desk and a turbine systems control and monitoring board with operator's work stations. The control room was also fitted with a screen display. In addition, the process computer system capacity had to be upgraded in connection with the control system renewal to handle the large volume of data yielded by the turbine automation. The automation interface was introduced at the Olkiluoto units 1 and 2 training simulator in September 2004, which made possible the training of operating personnel in its use.

Latest incidents at the Olkiluoto NPP (2008–2010)

Olkiluoto 1, Trip of the main circulation pumps and simultaneous loss of their fly wheel systems during scram 30 May 2008

There was a reactor scram and trip of main circulating pumps during start up after the annual outage at Olkiluoto unit 1 on May 2008. When the power was 60% the excitation system of the main generator caused high excitation current, and the generator output voltage rose to 125 % of the nominal 20 kV. The "115 % / 6 s over voltage relay", intended to drop the plant to house load operation in grid over voltage situations, opened the breaker on the high-voltage side of the main transformer disconnecting the plant from the 400 kV grid. When connection to the 400 kV grid was lost, the national grid no longer resisted the voltage increase, and the voltage at the plant's 6.6 kV busbars rapidly peaked to around 150 % for duration of 150 ms. The main and house load transformers saturated and their differential protection opened the generator switch and initiated a turbine trip. Electric motor driven pumps supplying hydraulic steering oil to the steam dumping valves stopped, preventing dumping of steam to the turbine condenser and leading to an automatic reactor trip and closing of the main steam isolation valves. The switch-over automatic connected the plant to the alternative 110 kV grid after a 2 s blackout time. All four emergency backup diesels started, but were not connected since the 110 kV feed was established successfully.

The voltage peak caused all six in-vessel type main coolant pumps to trip since the voltage in the intermediate circuit of the pump's frequency converters exceeded the 770 V protection level. The protection also disconnected the respective flywheels which provide additional inertia to the main coolant pumps in order to ensure sufficient cooling during transients. The flywheels are a separate set of motors which use their inertia to produce electricity as a generator for the main coolant pumps in case of a loss of normal power supply. The over voltage protection of these safety classified systems was thus inadequate. Two main coolant pumps could not be started later due to broken brake resistors.

There were no malfunctions in safety classified UPS systems of the plant or in any other systems besides main coolant pump drives. The flywheel generators are safety classified and were installed as part of the power upgrading project in 1997–1998. Since the pumps were at minimum speed in the beginning of the transient, the fly wheel equipment was not needed to slow down the pump ramps, and the transient had no consequences for fuel coolability. Starting at full power, a similar incident could lead a significant number of fuel rods to heat transfer crisis and possibly part of them to cladding temperatures endangering fuel integrity.

The event was classified as level 1 on the INES scale.

Several potential root causes were investigated. The primary cause of the incident was most probably a missing excitation current measuring signal and a software error of the voltage regulator. Root cause for the main coolant pump trip was inadequate dimensioning of the safety classified flywheel generator systems against overvoltages.

As a corrective action, the voltage condition of over 115 % for 6 s in the generator busbar will now trip both the generator switch and the excitation field switch in addition to the breaker on the high-voltage side of the main transformer. This will prevent the power peaks caused by the plant's own generator after a loss of the stabilising effect of the grid. A new condition of "simultaneous high excitation current (165 A) and more than 115 % over voltage for 0.5 s in the generator busbar" will cause a turbine trip and open the generator and the excitation field switches. The feeder circuit breakers of the main coolant pump drives will be disconnected if the voltage of 6.6 kV busbars is less than 80 % for 350 ms or more than 115 % for 50 ms. This will according to the transient calculations proactively prevent overvoltages from reaching the pump drives. If the voltage returns between 90 % and 110 %, the breakers will close again after 3 s stabilising time. In addition, all breakers feeding 6.6 kV busbars from station transformers will be disconnected if voltage exceeds 130 % for 30 ms. This will prevent the electrical consumers from calculated extreme overvoltages. Also the 400 kV switchyard busbar protection relay will open the generator breaker and all breakers feeding 6.6 kV busbars from station transformers. This will prevent generator induced overvoltages after a short circuit near the plant. The breaker on the high-voltage side of the main transformer is not opened if the generator breaker is closed.

Corrective actions mentioned above are intermediate solution that enables the licensee to provisionally continue the operation of the units. The solution obtained by altering and adding the plant's low safety class protection systems lowered the probability of tripping the main coolant pumps by voltage transients. However, from the deterministic point of view, the operability of safety classified components of the main coolant pump drives now relies on correct operation of lower and non-safety classified components and protections. The licensee is planning further plant improvements to completely remedy the situation.

The most important lesson learnt from the event was that the design of NPP's electric systems must take into account the transients coming from internal and external grid. The possible transients shall be analysed, the relay protection systems shall be designed to limit the transient voltages during and after disconnection of an electrical fault, safety critical components shall be dimensioned to withstand analysed voltage transients and software voltage limits set in the voltage regulator of the main generator can not be relied to limit transients generated by the generator.

Deficient leaktightness of pipe penetrations

A STUK inspector observed deficiencies in the leak tightness of the emergency cooling system pump facilities, the so-called H rooms, at the Olkiluoto nuclear power plant. The pipe penetrations through the walls had not been properly sealed. As the H rooms are also separate fire compartments, the problem also concerned the integrity of fire compartmentation. STUK required that TVO clarify the situation and launch corrective measures. TVO began repairs on the penetrations on 15 October 2008, and the work was completed on 23 October 2008. At Olkiluoto 1 and 2, 33 and 11 poorly sealed penetrations were repaired, respectively.

Both plant units have four so-called H rooms in their reactor buildings. These facilities include the necessary pumps for the reactor emergency cooling and the containment pressure relief. The H rooms have a connection to the containment condensation pool via pump suction lines. If a pump suction line breaks and the leak cannot be isolated, the condensation pool water leaking from the pipe will flow into the H room. The flow will end when the water levels in the H room and the containment condensation pool are equal. Plant design provides provision for such situations. If the H room is not leakproof, condensation water will also flow outside the H room, and the surface level of the condensation pool could become too low. Part of the reactor emergency cooling systems and containment pressure control functions would then be lost.

The probability of an unisolated pipe break as described above is very low. Pump suction lines have isolation valves that close automatically in case of a leak. No significant stress that would threaten the integrity of the pipes is targeted at the suction lines.

STUK required that TVO estimate the plant maintenance procedures due to the event and will make the necessary changes to the procedures. TVO executed a project to survey all pipe penetrations at the plant and to assess their maintenance procedures.

TVO delivered a report on the situation to STUK on 16 October 2008, and reported the issue in more detail in a special report in November, as required by YVL Guide 1.5. In February, the special report was complemented with test results.

In January 2009, TVO carried out tests on the pressure response of the penetration structure. Based on the test results, it was observed that it is unlikely that all H room penetrations meet the pressure response requirements, even after the repairs. Problematic penetrations have a fabric bellows on one side of the penetration and rubber bellows on the other side. Such a structure would not withstand water pressure from the fabric bellows side. TVO repaired the penetrations by installing rubber bellows on both sides of the penetration. The work was completed on 18 January 2009.

On the seven-level International Nuclear Event Scale (INES), the event was rated at level 1.

A common cause failure in main steam line outer isolation valve actuator at Olkiluoto unit 1

In a regular main steam line isolation valve test at Olkiluoto unit 1 during start-up after the annual outage on May 12, 2009, one outer isolation valve failed to open after it had been closed. The failed valve actuator (type AUMA SA30.1-B16) was sent to the manufacturer for inspections in order to find the cause of the malfunction. Based on the preliminary inspection, it was concluded that the cause was grease that had leaked from the actuator gearbox, and prevented switch-over from manual operation to the electric motor. The actuator was replaced on May 12, and the plant start-up was continued.

On June 2, 2009, the results of the complete inspection of the actuator by the manufacturer became known to the plant safety personnel and operation team, and on June 3, to the nuclear safety authority (STUK). The inspection had revealed that the initial assumption of the failure mechanism had been erroneous, and the actual reason was a mechanical failure of the planetary-type reduction gear, which is located between the electric motor and the actuator gearbox. In addition, it became known that another actuator – the one that had been taken from the storage in order to replace the failed one – had broken on May 12 during calibration runs prior to installation. It had been opened for inspection by the plant's own maintenance personnel, and it had been found out that the planetary reduction gear between the electric motor and the actuator gearbox was broken. This information had not been passed forward by the maintenance personnel, and both plant units were started prior to the information regarding the failure mechanism was known to the plant's safety personnel or the authorities.

When the failure mechanism became known, the nuclear safety authority ordered, on June 4, the plant operator to ascertain the operability of all eight main steam line isolation valves (planetary reduction gearboxes) of the two plant units by June 30. This was done by re-placing the remaining 7 of them (one having already been replaced with a new one after the failure), and inspecting the ones that had been removed. Several of the gearboxes showed early indications of fatigue in the planet gear teeth.

The event was rated as level 1 on the INES scale.

Periodic safety reviews at the Olkiluoto NPP

During the years 1996–1998 the overall safety review of the Olkiluoto plant was carried out by the licensee and independently by STUK in connection to the renewal of operating licences of nuclear power plant units. The safety documentation, including safety assessments done by the licensee, was submitted to STUK at the end of 1996. In addition to the review of the licensing documents such as Final Safety Analysis Report, STUK also made an independent safety assessment. The statement of STUK was given to the Ministry of Trade and Industry in June 1998. As regards radiation and nuclear safety, the main conclusions in the statement were that the conditions of the Finnish nuclear energy legislation are complied with.

The latest overall safety review of the Olkiluoto plant took place in 2007–2009 in connection of the periodic safety review. The operating licence for Olkiluoto NPP units 1 and 2, required that a comprehensive safety review (PSR) shall be carried out by the end of 2008. The operating licence also covers the interim storage facilities for spent fuel and medium and low activity operational waste, so these facilities were also included in the PSR. Regulatory guide YVL 1.1 specifies the contents of the PSR. For a separate periodic safety review, STUK shall be provided with similar safety-related reports as in applying for the operating licence.

TVO began preparations for the periodic safety review a few years after the current operating licence was granted. The PSR documentation was submitted to STUK for approval in the end of 2008. STUK made a decision concerning the PSR in October 2009. In the STUK's decision the licensee's PSR was approved as a comprehensive periodic safety review according to the licence condition. The decision included also STUK's safety assessment which provided a summary of the reviews, inspections and continuous oversight carried out by STUK.

The issues addressed in the assessment and the related evaluation criteria are set forth in the nuclear energy and radiation safety legislation and the regulations issued thereunder. Based on the assessment, STUK considered that the Olkiluoto Nuclear Power Plant units 1 and 2 meet the set safety requirements for operational nuclear power plants, the emergency preparedness arrangements are sufficient and the necessary control to prevent the proliferation of nuclear weapons has been appropriately arranged. The physical protection of the Olkiluoto nuclear power plant was not yet completely in compliance with the requirements of Government Decree 734/2008, which came into force in December 2008. Further requirements concerning this issue based also on the principle of continuous improvement were included in the decision relating to the periodic safety review.

The safety of the Olkiluoto nuclear power plant was assessed in compliance with the Government Decree on the Safety of Nuclear Power Plants (733/2008), which came into force in 2008. The decree notes that existing nuclear power plants need not meet all the requirements set out for new plants. Most of the design bases pertaining to the Olkiluoto 1 and 2 nuclear power plant units were set in the 1970s. Substantial modernisations have been carried out at the Olkiluoto 1 and 2 nuclear power plant units since their commissioning to improve safety. This is in line with the principle of continuous improvement of safety provided in section 7 a of the Nuclear Energy Act. The safety of the plant will be further improved during the current operating licence period. Based on the periodic safety review, TVO submitted to STUK action plans for the observed points requiring improvement. STUK included also some additional requirements in the decision relating to the periodic safety review. Systematic assessment and development of the diversity principle was required, including investigation of possibilities for residual heat removal independent of seawater. TVO shall present a report regarding the adequacy of the diversification at the plants and an action plan for developing the plants as a whole by the end of 2010. Another requirement considered plant modifications to improve safety in situations involving spurious opening of the turbine bypass valves.

As a summary of the review of the issues and documentation pertaining to the periodic safety review and the continuous oversight results, STUK noted that the safety of the Olkiluoto nuclear power plant units 1 and 2 is sufficient and the licensee utilises the necessary arrangements to continue the safe operation of the plants.

Planned and ongoing activities to improve safety at the Olkiluoto NPP

In Finland, the continuous safety assessment and enhancement approach is presented in the nuclear legislation. Actions for safety enhancement are to be taken whenever they can be regarded as justified, considering operating experience, the results of safety research and the advancement of science and technology. The implementation of safety improvements has been a continuing process at the Olkiluoto nuclear power plant units 1 and 2 since their commissioning and there exists no urgent need to upgrade the safety of these plant units in the context of the Convention.

There are several ongoing and planned safety upgrading measures at the Olkiluoto nuclear power plant. For example diversification of reactor water level measurements, reactor I&C system modernisation as well as construction of an emergency control room are under design. In addition, in the last periodic safety review, STUK requested TVO to perform a comprehensive survey on the sufficiency of diversification at the Olkiluoto units 1 and 2 and a plan on measures to develop diversification by the end of 2010.

The reactor water level measurement system consists of four parallel subsystems, two of which are sufficient for implementing the protection function (from high and low level). The subsystems are based on differential pressure measurement. TVO has studied possibilities to supplement the currently used low level measurement system with another system based on a different measuring principle. TVO has plans to implement the modification in annual outages in 2012. STUK has also required TVO to study diversification needs of the high reactor water level measurement pertaining to water level swelling by the end of 2010.

Current capacity of the spent fuel storage at the Olkiluoto site is adequate until 2014. TVO has plans to enlarge the interim storage by three new pools. Enlargement has been included in the Olkiluoto units 1 and 2 operating licence and the plant modification will be reviewed by STUK. Extension is planned to be ready in 2013.